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Station

Geologic, Geoarchaeologic, and Historical Investigation of the Discovery Site of Ancient Remains in Columbia Park, Kennewick, Washington

by Lillian D. Wakeley, William L. Murphy, Joseph B. Dunbar, Andrew G. Warne, Frederick L. Briuer

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Prepared for U.S. Army Engineer District, Walla Walla

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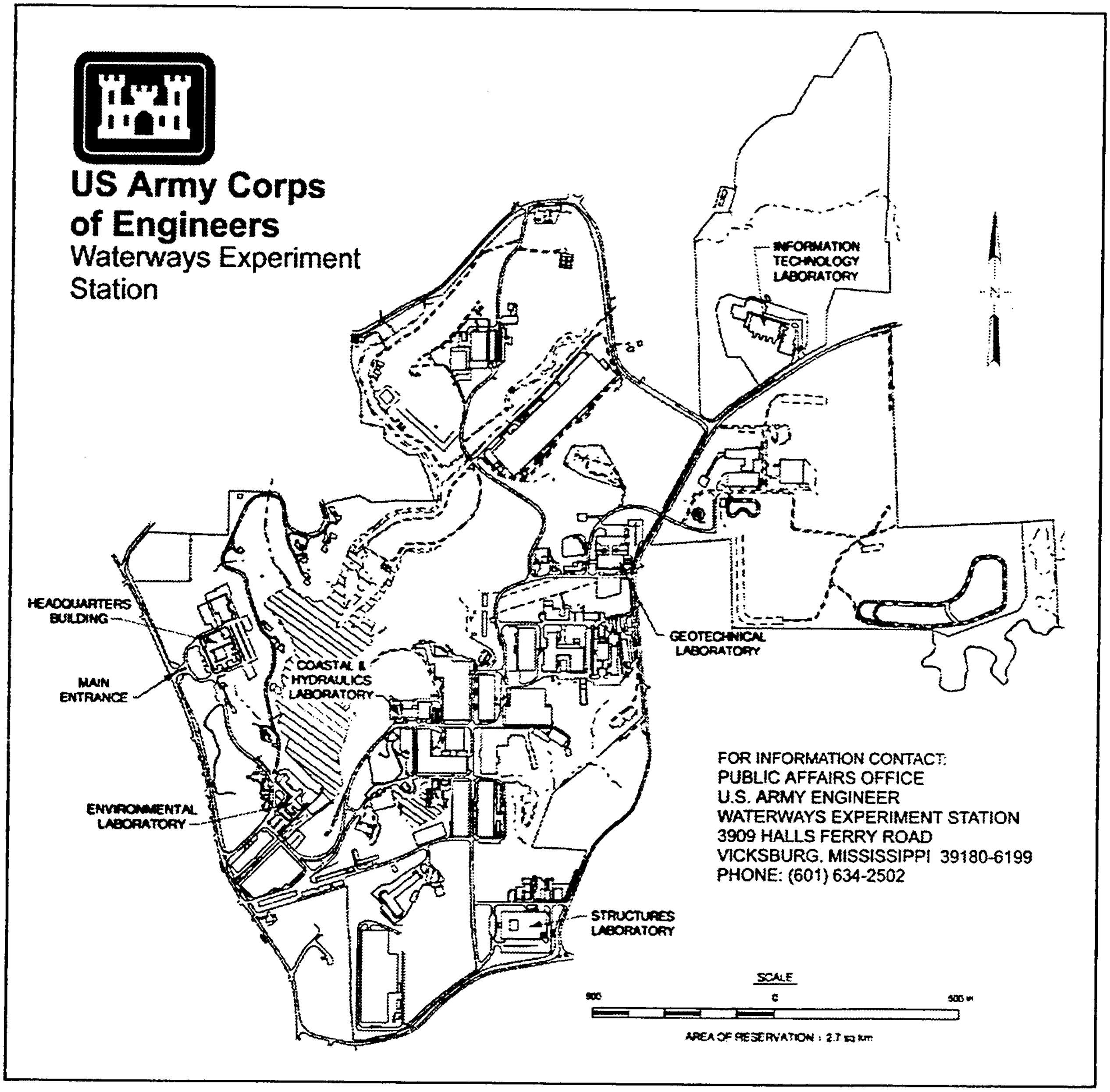

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Contents

List of Figures

Preface

This report describes the investigations conducted by the U.S. Army Engineer Waterways Experiment Station (WES) at the discovery site of ancient remains known as Kennewick Man in Columbia Park, Kennewick, WA. This study was conducted in support of the U.S. Army Engineer District, Walla Walla (CENWW), as authorized under Military Interdepartmental Purchase Request (MIPR) No. E86980020. Mr. John Leier was technical point of contact (POC) for CENWW during Phase One investigations in October 1997. Mr. Ray Tracy was CENWW technical POC during the December 1997 Phase Two investigations, which are the principal subject of this report. Ms. Lynda Nutt became CENWW POC following completion of Phase Two on-site activities, during preparation of this report. The report was revised and published under CENWW MIPR No. W68SBV81807671.

Dr. Lillian D. Wakeley, Chief, Engineering Geology Branch, Geotechnical Laboratory (GL), was principal investigator for the WES team and site coordinator during Phase Two field investigations. WES team members included Mr. Joseph B. Dunbar, Dr. Andrew G. Warne, and Mr. William L. Murphy, GL, and Dr. Frederick L. Briuer, Environmental Laboratory. Archaeologists Dr. Paul R. Nickens and Mr. Ray Tracy participated in the on-site investigations of Phase Two. Dr. Nickens conducted the research required to prepare Chapter 3 of this report describing the historical context of the Columbia Park site.

Dr. Douglas Wysocki, National Soil Survey Center, Lincoln, NE, also participated significantly in the on-site study. His ideas were excerpted into Chapter 7 of this report and are included as Appendix E. Dr. Andrei Sarna-Wojcicki, U.S. Geological Survey, Menlo Park, CA, performed confirmatory analyses on the tephra found on site. His letter report is included as Appendix H. Dr. Jack McGeehin, U.S. Geological Survey, Reston, VA, coordinated radiocarbon dating of soil samples, results of which are in Appendix I. The authors are grateful to these scientists for their expertise and enthusiasm and for the professional cooperation extended by their agencies during this study. We also are grateful to Dr. Francis R. McManamon, National Park Service, for his input to the scope of work and review of the report of this project.

Two groups that participated in on-site activities with the WES team had permits under the Archaeological Resources Protection Act (ARPA). Dr. Gary Huckleberry, Washington State University (WSU), wrote the first ARPA permit application for geological investigation of the Kennewick site and was principal investigator for the WSU team. Dr. Manfred Jaehnig was principal investigator for study under the ARPA permit submitted by the Confederated Tribes of the Umatilla Indian Reservation. The technical proposal from Dr. Huckleberry's original application and the on-site cooperation of both ARPA-permitted principal investigators contributed significantly to the technical merit of this study.

The report includes co-mingled English and metric units of measure. WES field research was conducted using metric units, the CENWW base map was surveyed in English units, and various other maps and sources of information used one or the other. In this report, measurements are reported in the units used for collecting the data. A list of conversion factors is provided.

Overall direction at WES for this report was provided by Dr. Lillian D. Wakeley, Acting Chief, Earthquake Engineering & Geosciences Division, and Dr. William F. Marcuson III, Director, GL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Robin R. Cababa, EN.

Conversion Factors, Non-SI and SI Units of Measurement

Non-SI and SI units of measurement used in this report can be converted as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
acres	0.4047	hectares
feet	0.3048	meters
feet	30.48	centimeters
inches	2.54	centimeters
miles (U.S. statute)	1.609347	kilometers
ounces (mass)	28.34952	grams
pounds (mass)	0.4535924	kilograms
pounds (mass)	453.5924	grams
square miles (U.S. statute)	2.5898	square kilometers
centimeters	0.0328	feet
centimeters	0.3937	inches
grams	0.002205	pounds (mass)
grams	0.035274	ounces (mass)
hectares	2.470966	acres
kilograms	2.204622	pounds (mass)
kilometers	0.621370	miles (U.S. statute)
meters	3.2808	feet
square meters	0.000247	acres
square kilometers	0.386101	square miles (U.S. statute)

Acronyms and Abbreviations

AMS	Accelerator Mass Spectrometry
ARPA	Archaeological Resources Protection Act
ASTM	American Society for Testing and Materials
°C	Degree Celsius
CENWW	U.S. Army Engineer District, Walla Walla
cm	centimeter(s)
CPC	Columbia Park Core
CPP	Columbia Park Profile
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
EEGD	Earthquake Engineering and Geosciences Division
EM	electromagnetic
ft	foot, feet
GIS	Geographical Information System
GL	Geotechnical Laboratory
GLO	General Land Office
GPR	Ground Penetrating Radar
I.D.	inside diameter
in.	inch(es)
km	kilometer(s)
m	meter(s)
MHz	megahertz

MIPR	Military Interdepartmental Purchase Request
MSL	Mean Sea Level
n.d.	no date
NGVD	National Geodetic Vertical Datum
p pp	page pages
POC	Point of Contact
PVC	polyvinyl chloride
SEM	Scanning Electron Microscopy
sq	square
USAE	United States Army Engineer
USGS	United States Geological Survey
WES	Waterways Experiment Station
WSU	Washington State University
XRD	X-ray Powder Diffraction
XRF	X-ray Fluorescence
YI&IC	Yakima Irrigation and Improvement Company
yr	year(s)
yr B.P.	years before present
±	plus or minus

Executive summary

During December 1997, a research team from the U.S. Army Engineer Waterways Experiment Station (WES) conducted geologic investigations at a site in Columbia Park, Kennewick, WA where human remains had been found in the summer of 1996. This study was conducted at the request of the U.S. Army Engineer District, Walla Walla (CENWW), in support of the Corps' resource stewardship responsibilities and to represent the Federal interest in legal issues related to the remains known as Kennewick Man. It was coordinated with concomitant studies of the same site conducted by two separate groups to which permits had been issued by CENWW under the Archaeological Resources Protection Act (ARPA).

The two principal questions addressed by the WES study were:

a. What age is indicated by geologic evidence at the study site? Asked another way, does the geologic evidence at the site support the age indicated by earlier age-dating of the remains at approximately 9,000 years?

b. Are there any indicators of specific cultural affiliation for the remains? Although the remains were not recovered in place in the sediments, it was important to recognize the possibility that cultural materials related to the remains might be recovered at the site.

Geologic studies to date have been conducted in phases to allow adequate time to coordinate all on-site activities with appropriate interested parties and to assure minimum physical impact to the site itself. Phase One was a preliminary site visit conducted by two WES team members with assistance by two CENWW team members in October 1997. During Phase One, the WES team defined the boundaries of the study site, identified some potentially significant stratigraphic features for establishing the age of the landform, and recommended a phased approach to the study and coordination with team members from the two ARPA-permit applicant groups.

Phase Two studies were conducted between 12 and 18 December 1997, and are the principal subject of this report. The focus of Phase Two field investigations was a 350-m exposure of sediments along the south shoreline of Lake Wallula, beginning approximately 50 m east of the location where the skull of the ancient remains was found and extending westward to include a volcanic

ash layer found during Phase One. The principal landform at this site is a terrace of the Columbia River, composed of fine-grained sediments that accumulated primarily in quiet water. This terrace may be correlated with terraces of early Holocene age at other locations along the Columbia River and described in published literature.

The volcanic ash or tephra layer at the Kennewick site is Mazama ash. This material originated from the volcanic eruption of Mount Mazama (now Crater Lake) identified by various authors to be at about 6,700 years before the present (yr B.P.). Because it occurs at many widespread locations throughout the Pacific Northwest, and because it is readily identifiable by its chemical signature and is of known age, this tephra is used as a time and stratigraphic marker in geologic and archaeologic studies in the western United States. Its presence as an in situ deposit near the terrace surface at the Kennewick site establishes that the landform associated with the ancient remains is more than 6,700 years old.

Stratigraphic horizons were traceable over the length of the study site, establishing that with the datable materials that are present, one can interpret the relative ages of the sedimentary units. One important traceable unit includes abundant concretions, which are accumulations principally of calcium carbonate and silica moved downward by groundwater over a long period of time. Geologic evidence indicates that the remains probably came from this concretion-rich sedimentary unit. Carbon-14 age dates of shells collected from two different locations above the concretion-rich unit indicate ages of greater than 6,000 years, although shells often yield erroneous age dates. However, the layers including volcanic ash and shells all indicate ages between 6,000 and 7,000 yr B.P. and are stratigraphically higher than (i.e., overlie) the sediment layer associated with the ancient remains. Therefore, the geologic features of the site support an age of more than 7,000 yr B.P. for the ancient remains. Age dates of WES-sampled sediments underlying the concretion-rich unit indicate ages of up to 15,000 yr B.P.

Although only a few hundred pounds of sediment were moved and screened, cultural materials were encountered in place in the stratigraphic units along the shoreline during this study. None of the cultural materials could be identified as being affiliated with the ancient remains. The materials identified as cultural were similar to known cultural materials from extensive reaches of the Columbia River shoreline and suggest repeated human use of this site in prehistory. The teams encountered no evidence of prehistoric burials during this site study. No cultural materials were encountered in sediment or core samples taken for study, and no cultural materials were removed from the site.

The activities of Phase Two confirmed that the landform in Columbia Park is old enough to have held the remains continuously for 9,000 years, and therefore the geologic setting is consistent with the age of the remains reported previously. The work was limited to the exposed reservoir bank and could not answer many research questions about the regional geologic setting and prehistoric land use.

1 Purpose and plans

1.1 Purpose of geologic investigations

During December 1997, a research team from the U.S. Army Engineer Waterways Experiment Station (WES) conducted geologic investigations at a site in Columbia Park, Kennewick, WA where the ancient human remains known as Kennewick Man had been found in the summer of 1996. The remains had been recovered from Lake Wallula, the Columbia River reservoir behind McNary Dam. The purpose of the WES study was to provide to the U.S. Army Engineer District, Walla Walla, (CENWW) answers to two questions.

Question 1: Does the geologic evidence at the site support the age indicated by earlier age-dating of the remains at approximately 9,000 years before the present (yr B.P.)? The hypothesis of the study team was that this question could be answered by careful geologic investigation of the general landscape setting and the stratigraphic features exposed along the reservoir shoreline, with follow-up laboratory analyses and interpretation of geologic materials collected at the site.

Question 2: Does the site hold any indicators of specific cultural affiliation for the remains? This second question was not as straightforward as the first. The remains were in shallow water in Lake Wallula when recovered, apparently having been exposed and moved into the shallows by processes of erosion. There were no data available to link them directly with an identifiable layer or depth in the sediments of the reservoir bank. Anecdotal evidence from CENWW scientists and natural resource specialists indicated that the bank had receded a meter or more by erosion during the 16 month interval between discovery of the remains and the geologic investigation. Therefore, if cultural artifacts were found during the geologic study, they could not be directly associated with the remains and still be in their original stratigraphic position. But it was important to recognize that cultural materials related to the remains or materials that might provide evidence about the age or circumstances of burial of the remains might be recovered from adjacent portions of the exposed bank line.

The WES team represented the Federal interest in gathering geological and geoarchaeological information germane to technical and legal issues surrounding the ancient remains. An additional function served by the WES was

coordination of on-site research conducted by two groups with study permits under the Archaeological Resources Protection Act (ARPA), as explained in the following sections.

1.2 Applications for ARPA permits

During August and October 1997, two research groups submitted applications to the CENWW for permits under ARPA to study the site where the Kennewick Man had been found during the summer of 1996. The remains had been recovered from Lake Wallula on property in Kennewick, WA owned by the U.S. Army Corps of Engineers. The first application was submitted from Washington State University (WSU) and the second from the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). The two groups proposed similar studies of the geologic setting and geomorphology of the site to answer questions about issues other than the remains themselves. Geologic questions to be explored during the proposed studies included many of the following issues addressed by the WES study.

1.2.1 Is there geologic evidence, independent of the age date of one bone fragment, to support the 9,000-yr age reported for the remains?

1.2.2 What geologic evidence associates the remains with a particular layer of sediment, and thus gives them a stratigraphic position?

1.2.3 Has the site been disturbed by human activity, or are its geologic features still in place?

1.2.4 What did the landscape look like when this individual was alive?

1.2.5 Was the site continuously or repeatedly used by people during prehistory (before the period recorded in historical documents)?

1.2.6 Was this likely to have been a desirable location for human activity during prehistory?

1.2.7 Is there any direct evidence of burial or burials at this site?

1.2.8 Is there evidence for a specific cultural affiliation for the ancient remains?

1.2.9 Are there properties of site geology, geomorphology, or geochemistry that could have contributed to the remarkable condition of preservation of the remains?

1.2.10 Does the evidence at the site present a logical sequence of geologic events? What interpretation for site geology presents the most logical picture?

Both ARPA-permit applicant groups proposed to address some of these questions through study of the landform. Each group proposed some form of excavation on the terrace surface to define the extent of the landform and document its geologic history.

1.3 Phase One WES study

In October 1997, CENWW requested that the WES provide a team of geologists to visit the site (this site visit was later named Phase One investigations), review the two ARPA permit applications in light of that visit, and recommend a course of action. The WES preliminary summary to CENWW during Phase One and other summary documents prepared between 24 October and 4 November 1997 included the following observations and recommendations:

1.3.1 Erosion is active at the site. Sediments that enclosed the ancient remains are being eroded away.

1.3.2 Sediments in the vicinity of the discovery site are more susceptible to erosion than are sediments in the areas upstream and downstream.

1.3.3 If the area is listed as an archaeologically significant site, some form of site protection should be installed before the next high-water season.

1.3.4 Geologic characteristics of the site observed during the Phase One site visit indicate that the landform age has the potential to be consistent with the reported age of the remains. The enclosing sediment is of a type that could have favored long-term preservation of the remains.

1.3.5 Multidisciplinary site study is essential for establishing site age, considering the intense scientific and legal interest in the discovery.

1.3.6 A phased approach to study would allow time necessary to communicate and negotiate among interested parties.

1.3.7 Phase Two site study should focus on the exposed bankline where erosion is active. This study should proceed before erosion removes any more of the bank, and before any portion of the bank is disturbed or covered by site protection materials.

1.3.8 The eastern end of the study area for Phase Two is a point downstream from the discovery site where the exposure of fine-grained sediments ends. The

study area extends upstream beyond the discovery site to include a bed of volcanic ash that was documented by the WES team during Phase One. This is a distance of about 350 m along the south shoreline of Lake Wallula where the sediments are exposed in a continuous near-vertical bank that extends approximately 1.2 to 2.2 m above the reservoir pool level. The sediments along this section of bank are eroding as stated in 1.3.1 and 1.3.2, and thus the study should include this entire area of active erosion surrounding the discovery site (Figure 1).

1.3.9 Phase Two study would provide a solid technical basis for planning follow-up investigations (potentially Phase Three), invasive study, or any other on-site research.

1.3.10 Both ARPA permit applications have technical merit, and both permit groups are well qualified to conduct site studies.

1.3.11 Conducting two or three separate site studies would be imprudent because of the potential damage to the site. A single site study involving participants from both ARPA-permit groups with Federal coordination would optimize the scientific value of the assessment and minimize adverse effects on the natural and cultural resources of Columbia Park.

1.4 Planning for Phase Two study

Between 4 November and 8 December 1997, WES scientists participated in discussions to define a plan of study for Phase Two investigations, based on a WES draft plan of 6 November. The intent was that this plan would serve the Federal interest and be acceptable to both ARPA-permit groups as a basis for their participation in site investigations coordinated by the WES. Discussions about the potential study included members of several Native American tribes and bands and their representatives; representatives of the U.S. Department of Justice and of the Bureau of Indian Affairs; representatives of the Office of the Solicitor of the U.S. Department of the Interior, of the Office of the Assistant Secretary of the Interior, and of the National Park Service; various technical experts from the Headquarters, U.S. Army Corps of Engineers; a representative of the Office of the Assistant Secretary of the Army; team leaders for both ARPA-permit groups; CENWW technical and legal representatives; and WES scientists.

Inclusion of all of these parties in the discussions provided a thorough technical review of the objectives, approach, and scientific procedures to be invoked or applied. It also provided the opportunity for participants to learn about the concerns of Native American groups and university researchers in regard to potential study at the Kennewick site. Both ARPA-permit teams were represented at a lengthy working session with CENWW and WES on

18 November 1997 to review and request additional changes to the study plan. The result of this month of negotiation was a plan for Phase Two site investigations to study the 350-m reach of Lake Wallula shoreline defined by the WES as the study area, coordinated by a WES/CENWW team and including both ARPA-permit groups. The scope of work for the WES-coordinated study is in Appendix A.

1.5 Orientation meeting for site activities

ARPA-permit teams and Tribal observers participated in an orientation meeting convened by CENWW and WES in Pasco, WA on 12 December 1997 following an initial site visit. A list of attendees is in Appendix A. During the meeting, the WES explained the basic outline of the study plan, and many details were discussed. Specific decisions made during that meeting that affected conduct of on-site activities included the following.

Artifacts would not be intentionally removed from the site. Any artifacts encountered were to be described and photographed on site by an archaeologist representing the Federal interest (Dr. Paul Nickens). Ecofacts such as non-human bone and shell could be removed from the site for subsequent age dating and analysis.

Small amounts could be scraped from sediments exposed along the bank to reveal details of shoreline stratigraphy or taken as samples for laboratory analyses without being screened on site. Sediments scraped during preparation of profiles would be screened on-site to identify any culturally significant materials. Sediments taken in cores below the water level would be taken off site and screened when studied. Duplicate cores would be taken using Corps equipment and made available to the WSU ARPA-permit group.

If any artifacts were inadvertently removed from the site in sediment samples, these would be returned to CENWW for appropriate action. Screening of sediments on site would be accomplished by the CTUIR ARPA-permit group.

Observers from all interested tribes and bands were welcome during on-site activities, and were independent of the ARPA-permit groups. Media coverage of the site study was scheduled for 15 December and described in CENWW-PA After Action Report dated 17 December 1997.

1.6 Participants and observers

The ARPA permits issued in December 1997 had restricted each permitted group to five participants on site at any time. This restriction was relaxed with minimal negative impact on the progress of the work, to accommodate the requests of many interested and contributing team members and Tribal

observers, and to increase discussion and interaction among researchers and observers. A list of study participants and observers is included in Appendix A. Rangers from the CENWW Natural Resource Office provided continuous and essential assistance at the site during the study. They are not listed as Columbia Park site personnel, but are listed as participants in the 12 December meeting. Other 1-day participants or observers may have been inadvertently omitted.

2 General geologic setting of Columbia Park

2.1 Background research

Familiarity with the regional geologic and geomorphic setting of a field site is an essential preparatory step before every meaningful geologic site investigation. In preparation for Phase Two investigations, the WES team reviewed the geologic history of the Columbia River system and the Pasco Basin, using the wealth of previously published material on these subjects (see References). Additional background information about prehistoric and historic land use and geomorphic processes was obtained through study of geologic and topographic maps of the region and of aerial photographs taken at several intervals beginning in the 1930's. The following summary of the geologic setting of the Tri-Cities area is derived from this background research. Huckleberry, Stafford, and Chatters (1998) also describe the general geologic setting of the study site.

2.2 Summary of the geologic setting of the Tri-Cities area

Geologic events of the past 15 million years have shaped and re-shaped the landscape in the Tri-Cities region (Baker et al. 1987, 1991; Baker and Nummedal 1978; Scott 1980). The area was covered with basalt flows during the extensive non-explosive volcanic eruptions of Miocene time (17.5 to 6 million yr B.P.). The dimensions of this basalt plain are almost too large to comprehend: nearly 4 km thick at its center, and covering 160,000 sq km. Subsequent folding of these basalt layers created low valleys such as the one that became the Columbia River valley. The area then uplifted, causing downcutting of the river through the basalt. This downcutting confined the river to a fairly narrow space, instead of allowing it to form a broad floodplain. The Columbia and Yakima[1] Rivers established their present drainage and altitude by late Pliocene time (Bjornstad, Fecht, and Tallman 1991; Fecht, Reidel, and Tallman 1985) and have experienced minimal change since then.

[1] "Yakima" is the River; "Yakama" are the people of the Yakama Tribe.

The basalt flows were covered by thick layers of wind-blown silt, called loess, during Pleistocene glaciation of the region. Loess caps the hills to the south of Kennewick, with the underlying basalt exposed on some lower hilltops and in washes from which the loess has been eroded by flash floods. The exposures of basalt and loess are shown on geologic maps of the area (Rockwell 1979; Reidel and Fecht 1994; Figure 2).

The cities of Kennewick and Pasco sit on vast deposits of poorly sorted coarse sediments deposited by huge catastrophic floods in late Pleistocene time, approximately 19,000 to 12,000 yr B.P. (Waitt 1980). These floods recurred many times over eastern and central Washington, creating the area known as the Channeled Scabland (Bretz 1923, 1969; Bretz, Smith, and Neff 1956; Baker 1978, 1981; Waitt 1987; many others). As described by Baker (1978, 17-18):

> The Channeled Scabland of eastern Washington consists of a spectacular complex of anastomosing channels, cataracts, loess "islands," and immense gravel bars created by the catastrophic fluvial erosion of the loess and basalt of the Columbia Plateau. The erosion and deposition that produced the scabland topography resulted from the failure of the ice dam impounding glacial Lake Missoula.

Various sources of geochronologic evidence indicate that the last of these floods to affect the Pasco Basin was between 12,000 yr B.P. (Mullineaux et al. 1978) and 13,000 yr B.P. (Baker 1973; Baker et al. 1991). Flood waters entered the Pasco Basin by many different flood routes, and were backed up into the Kennewick region by the constriction of Wallula Gap (O'Connor and Baker 1992), on the Washington-Oregon border southeast of Kennewick. In the Tri-Cities area, late flood events removed the loess from some areas, exposing basalt, and dumped in a very short time the unsorted gravel and sand that fills the space between the loess hills to the south of Kennewick and the present-day Columbia River (Reidel and Fecht 1994). The loess remains at elevations above the maximum flood events where it was too high to have been washed away.

The Columbia River has been held more or less in place since the end of Pleistocene time (approximately 10,000 yr B.P.) by deposits of coarse sediments. Very high energy and huge volumes of rapidly moving water associated with the glacial floods carried the gravel deposits to this location. The present river has less sediment-transport capability than is required to move them, and thus the coarse-grained flood sediments also help to confine the river and discourage wide meandering. Finer-grained sediments immediately adjacent to Lake Wallula in Columbia Park and upriver to Richland and the confluence of the Yakima River consist of materials that apparently post-date the catastrophic floods. They represent alternating erosive and depositional cycles of the Columbia River during Holocene

and recent time, when thick slackwater deposits accumulated in the Pasco Basin (McDonald and Busacca 1992).

Prehistoric volcanic eruptions from Mount St. Helens, WA and the former Mount Mazama, now Crater Lake, OR, covered parts of the Pacific Northwest with volcanic ash during Pleistocene and Holocene times (Sarna-Wojcicki and Davis 1991; Sarna-Wojcicki, Champion, and Davis 1983; Waitt 1980; Bacon 1982; Nelson, Carlson, and Bacon 1988). A major eruption of Mount St. Helens is known to have occurred about 13,000 yr B.P. The final caldera-forming eruption of Mount Mazama occurred about 6,700 yr B.P. Both of the eruptions distributed volcanic ashes across the Pasco Basin where they became interlayered with Missoula flood deposits or other sediments. The Mazama tephra is included locally in both aeolian and alluvial deposits (Waitt 1980; many others). Evidence of both of these volcanic events have been used widely to assist in dating the ages of landforms in areas from California and Nevada into southern British Columbia and Alberta (Davis 1978; Williams and D'Auria 1991; Baker et al. 1991). These discontinuous ash layers are keys to establishing the stratigraphy and age affiliation of cultural resources throughout the Pacific Northwest. At the outset of the study, there was a high probability that the ash layer documented by the WES team during Phase One had originated from one of these two volcanic events.

3 Historic context for the Columbia Park site

3.1 Introduction

This chapter establishes a historic context for the locale where human remains, commonly referred to as Kennewick Man, were discovered. The location where the remains were encountered is referred to as the Columbia Park site, located along the south shore of the Columbia River within Benton County and the town of Kennewick, WA. Members of the public first observed the skeletal remains in late July 1996. Subsequent events and assorted preliminary scientific analyses indicate the well preserved, nearly complete osseous remains of an adult male that have been radiocarbon dated at ca. 8,500 to 8,950 yr B.P. (Taylor et al. 1998). The degree of preservation and age of the remains yield high levels of cultural and scientific significance and importance. The following discussion summarizes the historical setting for the parcel of land where the remains were encountered. It includes a synopsis of the aboriginal history of the area, as determined by previous research and a discussion of the sequential historical development of the area by White explorers, settlers, and townspeople, with special examination of past land use at the site.

This discussion provides a historical and cultural backdrop for the on-site geological studies at the Columbia Park site that occurred in December of 1997. See Appendix B for a recapitulation of the circumstances of the discovery and subsequent events that occurred prior to the taking possession of the remains by the U.S. Army Engineer District, Walla Walla, (CENWW) in September of 1996.

3.2 Methods

Documentary materials and data on which this discussion is based come from several sources. Information on file at the CENWW office in Walla Walla, along with other data compiled in conjunction with the ongoing events related to the Columbia Park discovery, are the primary baseline for this analysis. Particularly useful are maps, aerial photography, and land ownership records developed in the late 1940's and early 1950's in conjunction with completion of

the Corps' McNary Lock and Dam/Lake Wallula Project. In addition to examination of extant archaeological and historical literature, unpublished data were sought from local and regional repositories and offices, including local historical societies, libraries, museums, and county offices, as well as the Washington State Office of Archaeology and Historic Preservation and Public Lands Survey Office in Olympia, WA. Copies of aerial photographs taken in 1930 along the Columbia River were obtained from the Corps of Engineers Seattle District office, and various versions of historic topographic maps were reviewed at the U.S. Geological Survey Library at the Denver Federal Center, Denver, CO. Limited interviews were conducted with some current Tri-Cities residents whose families lived along this stretch of the Columbia River prior to the acquisition of the land in 1950 by the U.S. Government.

3.3 Prehistoric and historic aboriginal use of the area

Although generally known to have been intensive and longstanding, American Indian occupation and use of the area that today includes the subject site and the surrounding Tri-Cities of Kennewick, Pasco, and Richland is not wholly understood for the archaeological period. The once extensive archaeological record in this area has generally suffered during the past 100 years or so from land and water project developments and, in some unfortunate instances, outright destruction and vandalism. Several archaeological investigations have been conducted in the general area, beginning professionally with archaeological surveys associated with development of the Columbia River for water projects in the mid to late 1940's. Archaeological surveys and excavations at selected archaeological sites completed in conjunction with the McNary Lock and Dam project are summarized in two Bulletins of the Smithsonian Institution Bureau of American Ethnology (Osborne 1957 and Shiner 1961). As part of this early work, archaeological site 45BN52 was first recorded in 1948 and is the closest recorded site to the Columbia Park site, although it is located about one mile upstream from the current project area.

In later years, additional field surveys and excavations were completed, mainly by the Mid-Columbia Archaeological Society, at several sites in the Tri-Cities area. Summaries of the efforts are found in the Corps' *Cultural Resources Management Plan for the Walla Walla District: The Ice Harbor Cultural Resource Management Unit* (Western Heritage n.d.) and in the National Register of Historic Places Nomination Form for the Tri-Cities Archaeological District (Western Heritage 1983). The most recent and comprehensive overview of the regional prehistory (and ethnohistory and history) is the voluminous *National Register of Historic Places Multiple Property Documentation Form - Historic, Archaeological and Traditional Cultural Properties of the Hanford Site, Washington* (Department of Energy 1997). It primarily covers the stretch of the Columbia River just north of the Tri-Cities. The most recent field effort along the shoreline of Lake Wallula was conducted by the Cultural Resources

Protection Program of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) during which 44 of 105 known archaeological sites in the reservoir were visited and erosion impacts assessments completed (Jaehnig 1996, 1997). As part of his analysis of the artifacts collected from the Columbia Park site, Sappington (1997) also summarized the archaeological background for the subject area.

Although a few intensive archaeological studies have actually been completed and fully reported in the Tri-Cities area, a 10-mile stretch of Columbia River shoreline, including the Columbia Park site, was nominated for listing on the National Register of Historic Places in January 1983 (Western Heritage 1983) and was formally listed as the "Tri-Cities Archaeological District" on 10 October 1984. According to the nomination form, "The proposed...District includes 20 prehistoric sites...and contains the densest population of known prehistoric sites along the middle Columbia and lower Snake Rivers. The district includes open campsite, burials, and housepit sites." Based on past archaeological efforts, this district has been occupied by American Indian peoples more or less continuously for the last 10,000 years and into historic times as well. Sappington (1997), however, believes that the available documentation reflects that few if any of the Tri-Cities archaeological sites date to cultural periods older than 2,500 yr B.P., and that many of the known sites were occupied within the past 200 years.

When the Lewis and Clarke Discovery expedition entered the area now encompassing the Tri-cities area in October of 1805, after having traveled down the Snake River to its confluence with the Columbia, they encountered numerous Indians engaged in the taking of Chinook Salmon. This area, which includes the junctions of the Snake, Yakima and Columbia Rivers, had long been a gathering ground for several people of Middle Columbia tribes, including the Yakama, Wanapum, Palouse, Walla Walla, Cayuse, and Umatilla (cf. Relander 1986, Ronda 1984, Suphan 1974). According to the Lewis and Clarke journals (Ronda 1984, pp 164-167), the explorers specifically identified the groups present at that time upriver from the Snake-Columbia confluence as Wanapum and a sub-group of the Yakama[2] known as the Chamnapums.

Because of the Indian activities occurring at this area, the expedition spent extra time here before continuing on down the Columbia River. During this sojourn, Clark, with two of his party, took a small canoe and traveled upriver on the morning of 18 October. They traveled past the Columbia Park site, probably to the vicinity of the Yakima-Columbia confluence, observing many mat-lodge fishing villages and fish-drying scaffolds along the banks. The small reconnaissance party stopped at one of the Wanapum camps along this stretch of the Columbia and was given food. Later, in his journal Clarke recorded

2 "Yakama" are the people of the Yakama Tribe; "Yakima" is the River.

observations related to the Wanapum's physical characteristics, clothing, and villages. The observations noted by Clarke served as the basis for a full-page color illustration of a Wanapum village on the bank of the Columbia River that appeared in the February 1948 issue of The National Geographic Magazine (Stirling 1948). The magazine illustration is based on a painting of a somewhat stylized setting that represents a locale very near the present project area.

Ethnographic information collected from Wanapum Elders around 1950 indicates the richness of the historic occupation and use of the present-day Tri-Cities area (see Relander 1986 and various files in the Relander Collection at the Yakima Valley Regional Library [Rankin n.d.]). The large permanent village encountered by Lewis and Clarke at the Snake-Columbia confluence was called "Kosith" in the regional Sahaptin language. In addition to serving as a village for members of several area tribes, it was a principal place for taking lamprey eels in the late summer. In the fall, the Columbia in this stretch was a fishing place for Dog Salmon (Fall Chinook). The general area now occupied by the town of Kennewick was called "Anwash" by the Wanapum and was occupied by scattered family groups. The major Chamnapum village, "Chamna," was located upstream from the Columbia Park site at the Yakima-Columbia confluence. The name "Kennewick" is said to be a Sahaptin word meaning "Grassy Place"; however, Wanapum Elders interviewed in 1951 had no recollection of this word (Relander 1986, p 297).

The Wanapum still were using the open pasture area that includes the Columbia Park site as a seasonal camping area in the late 1940's and early 1950's. According to Robert Tomanawash, Wanapum Elder, the Wanapum camped in the area during the late summer months while doing seasonal work in the fields and orchards of nearby farms (personal communication, February 1998). This temporary and seasonal camping pattern ended in the 1950's after establishment of the Columbia Park recreational area.

The region that includes the present-day project area was formally ceded to the United States in 1855 via a treaty signed by representatives of a confederated grouping of tribes that included the Walla Walla, Cayuse, and Umatilla. This treaty, one of nine concluded at that time with many Indian Tribes in the Washington and Oregon Territories, also established the reservation in northeastern Oregon known today as the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). In addition to exclusive rights on the reservations, this and other treaties included certain reserved non-reservation rights for the Indian Tribes, including fishing at "usual and accustomed" grounds, hunting rights, right to dig roots and gather berries, and pasturage rights "on open and unclaimed lands" within the larger ceded lands.

These reserved off-reservation rights have been and continue to be the object of much scrutiny and contention. For the Columbia Park site itself, there are at

least two interesting side notes. The first is a special provision in Article 5 of the Treaty that stipulated "...that Pio-Pio-mox-mox [a leader of the Walla Walla Tribe and treaty signer] is secured for the term of five years, the right to build and occupy a house at or near the mouth of the Yakima River, to be used as a trading-post in the sale of his bands of wild cattle ranging in that district." In the official record for 7 June of the 1855 council between the Indian agents for the territories and the tribal representatives, Pio-Pio-mox-mox requested and was granted the temporary right to build the trading post to sell cattle to the passing Americans, and to take fish while he lived there (Swindell 1942, p 441).

Secondly, although Lewis and Clarke noted the fishing activity in the area in 1805, and later Wanapum Elders indicated that the area was used for both eel and salmon taking, the Tri-Cities area was not included in early efforts to determine where "usual and accustomed" fishing places occurred in the region. The first of these surveys was conducted by Gordon (1889) and focused primarily on major fisheries. A second survey was completed in 1941 by Swindell (1942) and included extensive interviews of Indian elders and field visits. Once again, this project did not offer information on traditional fishing places in the Tri-Cities. However, Swindell queried the informants only about currently used fishing grounds at the time of his survey, not about those that might have been used historically but were abandoned for some reason (e.g., encroachment by other groups or changes in fish runs).

3.4 Non-Native settlement and historical developments in the vicinity of the project area

To establish a historical overview for examining past land use in the vicinity of the Columbia Park site, various historical records and sources were consulted. The historic overview is presented below in the form of a land use time line for the period 1853 through 1953. The first year in the time line represents the first substantive effect on the landscape from a change in land use. The terminal date corresponds to establishment of Columbia Park.

1853 - Establishment of the first Federal road

Soon after the Territory of Washington was formed, Congress authorized construction of a military wagon road between Fort Walla Walla and Fort Steilacoom on Puget Sound to the west. Being the first wagon road built by the Federal Government in the Pacific Northwest, the road was established when Secretary of War Jefferson Davis directed Captain George McClellan to survey and construct the route. On early maps of the area, the route is indicated as following closely along the south bank of the Columbia River, close to the Columbia Park site in Section 34, Township 9 North, Range 29 East. Informed of the military road, the Longmire Wagon Train party, the first group to divert from the Oregon Trail and venture across the new Territory, left the Oregon

Trail at Pendleton and traversed the military road through the project area in mid September, arriving at Puget Sound in October 1853.

Late 1850's through 1870's - Military road, exploration, and river commerce

Traders, explorers, missionaries, railroad engineers, settlers, and Government surveyors passed along the military road. As early as 1859, steamboats were operating on the Columbia near the project area and at the confluence of the Yakima and Columbia Rivers. Cattle and sheep ranching was established in the region to supply mining districts in British Columbia and throughout the Columbia River Plateau.

In 1864, General Land Office (GLO) surveyors described the land in Township 9N, Range 29 East as "...useful for grazing...the soil is sandy and covered with a growth of sagebrush and bunch grass...Along the banks of the Yakima and Columbia Rivers, and also on Bachworth's (present-day Bateman or River View) Island there is a heavy growth of grass valuable for hay; the island and a portion of Sections 29 and 30...is claimed by four persons... engaged in making hay which they ship down the Columbia to Wallula and Umatilla City..." (Henry 1865, p 212). In their field notes and map, the GLO surveyors noted the military trail through the present project area. The military trail through the project area also is prominently indicated on the map included in the Symons Report of 1882 (Symons 1967). The Symons party traveled through this segment of the Columbia in September and October 1881. Although reporting regular Fall Indian fishing activity at White Bluffs upriver from the Tri-Cities, they did not mention similar activities along the river in the vicinity of the Columbia Park site.

1875 - Postal Service

A mail service route was established between Yakima City and Wallula through the project area in 1875, with a post office constructed at the mouth of the Yakima River. Stage service operated along this route until completion of the Northern Pacific Railroad in 1884 through 1885.

Early 1880's - Ranching and railroads

Ranching declined in the area in the early 1880's with the coming of the railroad. Extensive farming and overgrazing caused subsequent range depletion. Completion of the Northern Pacific Railroad to Ainsworth at the confluence of the Snake and Columbia Rivers in 1883 accelerated settlement of the region by wheat farmers and the associated closing of the open range.

1885 through 1900 - Irrigation, railroads, and settlement

Agricultural development did not begin in earnest until initiation of large-scale irrigation projects, and establishment of rail lines to provide access for products and settlers and a means of shipping local products. Rail companies also had capital to finance irrigation projects. The Northern Pacific Railroad eventually extended west from Ainsworth through the project area and up the Yakima River valley. The towns of Pasco and Kennewick were established in 1884. A bridge was constructed over the Columbia River in 1888 to facilitate travel between the newly developing towns.

Settlement of the general area at this time was closely tied to the construction of irrigation systems. There was a "great rush to file on land along projected ditches. Thousands of acres were entered at the Walla Walla land office under the Homestead and Desert Land laws in the winter of 1888-1889" (Parker 1979, p 10). At the same time the town of Kennewick was platted in 1893 by the Yakima Irrigation and Improvement Company (YI&IC), the company completed construction of the Kennewick Irrigation Canal. The YI&IC took control of the odd-numbered land sections in the lower Yakima Valley, and purchased land from the Northern Pacific Railway (which owned the even numbered sections), to gain the right-of-way for the canal.

The first major irrigation canal constructed in the region, the Kennewick (Columbia) Canal, extended from a headgate at the Horn Rapids Dam on the Yakima River southeast along the Columbia River through the project area toward Kennewick and beyond. The canal system, today owned and operated by the Columbia Irrigation District, was nominated for listing on the National Register of Historic Places in 1993 (Boreson 1993) and determined eligible by the Washington State Historic Preservation Office in 1994. During the Panic of 1893, the YI&IC went bankrupt, and a large "break" occurred in the canal, causing a slow-down in irrigation and agricultural development in the vicinity of the project area and Kennewick.

1900 through 1930 - Irrigations mergers, farming, and the River Road

By 1902, canal construction resumed with the merger of the Kennewick Land Company and a subsidiary of the Northern Pacific Railway, the Northern Pacific Irrigation Company. Delivery of irrigation water resumed in 1903, resulting in an increase in agricultural development in Kennewick and along the River Road. Homes and farms developed along River road from Finley/ Kennewick to the Richland Y area, located below the Yakima-Columbia River confluence near Bateman/River View Island. Fruit orchards, alfalfa fields, and vegetable gardens were cultivated adjacent to the project area. Small dairy operations also were established along the river shore. A large dairy and hog farm was established on Bateman/River View Island at the mouth of the Yakima

River. Early residents in the vicinity of the project area used irrigation water from the Kennewick Canal instead of from the Columbia River because it was easier to use gravity flow from the hillside canal.

In 1911, the Washington State Highway Department designated River Road as part of the route of the Inland Empire Highway in eastern Washington. In 1914, the road was designated as part of the first transcontinental highway system, known as the Yellowstone Trail, from Plymouth Rock, MA to Puget Sound, WA. The River Road was part of this transcontinental route until 1925 when the designation was moved to a shorter cross-state route west from Spokane. The River Road was paved with concrete in 1926. Soon after, the road became part of U.S. 410, resulting in an increase in commerce, agricultural development, and settlement in Kennewick and Pasco.

1930 through 1953 - Depression, the Hanford Engineer Works, and post-war boom

Even with the economic downturn, numerous farms, homes, and orchards were established in the vicinity of the project area. Smaller tracts were situated along the waterfront. Each riverfront farm had a house, barn, orchard, and smaller agricultural outbuildings. Residents constructed booms in the river to obtain driftwood for use as firewood. Farms had cattle, sheep, turkeys, and cultivated potato and alfalfa fields as well as fruit orchards. Commercial fishing occurred near Bateman/River View Island, mainly for sturgeon.

Traffic increased considerably along the River Road through the project area during World War II, when the road became the main route between Pasco/ Kennewick and the Hanford Site north of Richland. Population then increased along River Road, resulting in numerous property transactions.

The Flood of 1948 ravaged the area. During 1950 and 1951, the U.S. Army Corps of Engineers' McNary Lock and Dam Project resulted in the acquisition by the Federal Government of the land in the immediate project area, and the rest of River Road through this area. A total of 700 houses and other structures was moved or demolished. In 1953, the four-mile-long 300-acre public recreation area designated as Columbia Park was established on the south shore of Lake Wallula when the land was leased to Benton County Parks and Recreation Department.

3.5 Past land use at the Columbia Park site

The location where the human remains were discovered lies in the NW ¼ of Section 34, Township 9N, Range 29E, Benton County, WA. To identify and evaluate historic land use activities at this locale, several historic documents, maps, and aerial photographs that cover the area were reviewed. The

documentation examined and their implications for land use are summarized in this section.

The Government Land Office (GLO) maps made in August of 1864 show only the military trail passing along the bank of the Columbia River in this ¼ section. The accompanying field notes do not include comments specific to the project area. The Columbia Park site is shown as being located in Lot Number 3. The northern portion of this lot was at that time truncated by the Columbia shoreline. These maps are on file at the State of Washington, Department of Natural Resources, Public Land Survey Office, Olympia, WA.

A low-level, oblique photograph was taken in 1907 from the roof of a home near where the present Columbia Park Golf Course is located. The home was one mile or less east of the Columbia Park site. The photograph shows the view to the west along the River Road. Badger and Rattlesnake Mountains are visible in the distance. Although it is not possible to identify exactly the Columbia Park site in this view, it is indicative of the early twentieth century landscape along the River Road and Columbia River shoreline. The general area at this time was sparsely populated by farms, with considerable pastureland and a young orchard in the view. The road itself was still dirt and formed a slightly winding route along the river shore. (Photograph reproduced in Woehler 1994.)

U.S. Geological Survey Pasco 30' Quadrangle Map of 1917 (Scale 1:125,000), is based on field surveys in 1904 and 1914. This map shows what is apparently the old military trail close to the shoreline, seeming to pass over or very close to the Columbia Park site, and a house just down river (to the east). The primary route known as the River Road, the irrigation canal, and the railway are all indicated as being in place just to the south. No residence is indicated on or near the site at this time. There is no indication of actual land use at the project area reflected on the map.

Aerial photograph from a March 1930 flight has a scale of 1 in. = 1000 ft. This large-scale photograph shows the tract of land as an open, presumably pasture setting. Because of the time of year, the water level is low. Areas of cobble beaches extend into the river along the shoreline. The shoreline itself exhibits dense woody vegetation, visible even at this time of the year. Immediately south of the River Road, orchards and residences are present. The building shown on the 1917 topographic map appears to have been located in the lot immediately east of the one that includes the Columbia Park site, based on the presence of a cluster of trees. (Aerial photographs from this early series are on file at the U. S. Army Engineer District, Seattle, WA.)

Maps included in *Metsker's Atlas of Benton County, Washington,* (1934, 1943) indicate land ownership for Benton County. They do not indicate land use. In 1934, the tract of land that includes the Columbia Park site was owned

by C. M. Kimpel, the tract to the west was owned by V. B. Martin, and the four tracts to the east were still owned by the Columbia Irrigation District. By 1943, the tract including the project area is shown as being owned by J. A. Pierce, with V. B. Martin still owning the lot to the west. The three tracts to the east were then shown as belonging to Wayne Houston. There is an apparent discrepancy between the 1943 Metsker Map and the Corps of Engineers land acquisition records discussed below. The Corps documentation indicates that Mr. Pierce actually owned the tract just east of the one including the project area. This discrepancy may be due to the scale or accuracy of one or the other map, or it could indicate that a boundary changed, resulting in a newly configured tract. The question of actual ownership is not a critical one for this discussion. The land use pattern of pastureland did not change.

In conjunction with development and construction of the McNary Lock and Dam, and the subsequent raising of Lake Wallula, several planning and engineering documents and maps were prepared by the Corps of Engineers between 1944 and 1953. A representative selection of these records, all available at the U.S. Army Engineer District, Walla Walla, include the following maps and photographs.

Multiple-sheet small-scale planning maps, with a scale of 1 in. = about 350 ft, were completed in 1944. Subsequent editions added different project-related information. Among information indicated on these maps are topography, normal high water marks, normal pool level, and the high water mark for the 1948 flood. Also shown are project features such as levee locations, pre-project building locations, and previous land use for acreage within the proposed project administrative boundary.

The area including the Columbia Park site is indicated in 1950 as being pasture from the river's edge to the highway (today's Columbia Avenue), with no nearby buildings. Land south of the highway was well developed at the time, with residences, extensive orchards and the sizable Hillside Trailer Camp being located across the road immediately south of the Columbia Park site. The high water mark for the 1948 flood (349.5-ft elevation) would have inundated nearly all of the pastureland located north of the highway.

A series of vertical aerial photographs, dated 25 June 1950, and the oblique ones discussed below, provide the best visual overview of the final land use pattern before the property was acquired by the Government. The tract from which the Kennewick human remains were removed is clearly shown as undeveloped pastureland. Although a fairly dense growth of trees and brush is evident along the shoreline, the land is fairly open with few trees between the shore and the highway. Intensive orchard development, many residences, and the Hillside Trailer Park are clearly visible. A large house with circular drive, located in the third tract to the east, is the closest residence along the river. This

house was built in 1939 by George and Johanna Austin and later moved in 1950 to a location about five miles away after the Government acquired the property (Woehler 1994). During the Flood of 1948, the Austin residence was encircled by floodwaters, but industrious sandbagging and pumping efforts on the part of the family kept water from entering the house.

Written documentation associated with acquisition of the land by the Corps of Engineers in 1950 to 1952 includes land tract maps, correspondence, warranty deeds, and court records as appropriate to specific tracts. Based on review of these documents, and comparison with contemporary aerial photographs, the Columbia Park site appears to be located in the northeast part of Tract No. Q-1128. According to the warranty deed filed on this tract, dated 16 June 1950, it included about 2.2 acres and at the time of Government acquisition was owned by John E. and Myrtle C. Strandberg. The Strandbergs were paid $6000 by the Government for their property. The warranty deed for this property did not list any reservation on the part of the sellers to remove improvements (e.g., buildings, water pumps, or tanks).

The next closest parcel, Tract No. Q-1127, is located immediately east of the Columbia Park site, and was owned by J. A. and Vera K. Pierce. Court records from 1952 do not indicate reservation to remove any existing improvements on this tract, either.

The Corps of Engineers Master Plan for Development and Management of McNary Reservoir was issued in July of 1952, along with supporting maps and photographs. It lays out the future land use of the area including the Columbia Park site.

> The four mile section of shore line extending from Kennewick to Island View has been designated for general public and organized group use and called Columbia Park by the local people interested in its development. It consists of 300 acres of Government-owned land bounded on one side by the reservoir and on the other side by the new limited access highway... About 90 acres are situated above the flood zone. The old highway, soon to be abandoned, runs the length of the area and is situated largely above the average flood level. This park unit contains more existing shade and ornamental trees than any other section of the shoreline and has fair to good soil cover. It has been used for fruit orchards, residential and commercial purposes although the orchards will be removed in clearing operations. The city of Kennewick and Benton County plan to jointly develop and operate this area as a city-county waterside park. (Corps of Engineers 1952, pp VII 17-18).

The master plan map for Columbia Park indicates that the area including the Columbia Park site was proposed as part of a larger waterside picnicking area, and future tree planting was planned in the vicinity.

The 1952 master plan document utilized a series of low-level oblique aerial photographs, taken on 7 February 1952, to illustrate project plans. One of these photos available in the CENWW photographic archives illustrates the overall land use and vegetative setting at and adjacent to the Columbia Park site at the time the property was acquired by the Government. Additional sequential aerial photographs were reviewed to identify possible changes in land use at the project area that might have occurred during the past 40 years. Specifically, aerial photographs from 1955, 1962, 1991, and 1996 were examined. The only change noted in the vicinity of the Columbia Park site is the expected increase over time of the larger woody vegetation in the area that was once pastureland. Apparently, vegetation in this section of Columbia Park was allowed to grow unabated, despite the original plan for it to be part of a larger picnic area. All of these aerial photographs are on file at the CENWW headquarters.

4 On-site investigations

4.1 Introduction

December 1997 field activities consisted of obtaining data to interpret the geologic, stratigraphic, and geoarchaeologic conditions and chronology of the 350-m study reach along the bankline with minimum impact to the site itself and with adherence to reproducible procedures with essential scientific rigor. The WES team used four approaches to obtain field data. These were 1) detailed geologic, pedologic, and archaeologic examination and sampling of 12 bank profiles within the 350-m study reach; 2) sampling of subsurface soils riverward of the bank using a Vibracore sampler; 3) geologic, pedologic, and archaeologic reconnaissance of the entire exposed bank and beach in the study area, and 4) a limited geophysical survey of the area near where the remains were found (the discovery site). For these activities, the pool level of Lake Wallula was lowered by about 0.6 m for 2 days of the study to facilitate access to the bank and to underlying sediments. The lower pool level also enhanced site access for observers and journalists.

4.2 Definition and selection of bank profiles

The scope of work had proposed a total of 15 bank profiles at 25-m intervals within the study area. Profile locations were selected by the WES team with input from the ARPA teams during general site reconnaissance during the first 2 days on site (Figure 3). Profile locations were selected to avoid areas that were obviously disturbed by recent natural processes, and those that had been modified during historical time (there are some 20th-century trash pits and a drainage pipe exposed in the bank). The profiles studied were judged to have a high probability of stratigraphic integrity, and to require minimum cutting of tree roots or other vegetation to minimize site disturbance.

Some potential locations for profiles were eliminated because dense vegetation restricted access for people and equipment. Profiles were positioned to require removal of only small volumes of sediment, again to minimize site disturbance and to avoid long preparation times for each profile as the sediments were screened. At several locations, profiles were stepped back to minimize disturbance and screening and to allow more time for study of the entire site (Figure 4).

As a result of the considerations for minimum impact, time effectiveness, and access for people and equipment, 12 profiles were defined and prepared for study. The purpose of the profiles was to provide clean windows for study of soil and stratigraphy and to permit correlation of strata and detailed physical features along the study reach. Profiles were spaced more closely in the immediate vicinity of the discovery site. Clearly defined profiles also assured that all study groups had access to the same exposures and had common reference points available for their notes and photographs, to facilitate technical discussion.

Bank profiles were designated by stations in meters, with station 0+00 at the east end of the study reach near a contact between the fine-grained sediments associated with the ancient remains and an exposure of bedded gravels along the reservoir shoreline to the east. The 12 profile designations are Columbia Park Profile (CPP) 005, 044, 054, 080, 093, 125, 166, 200, 233, 268, 296, and 334 (Figure 5). Station numbers represent the distance in meters from the origin, which is station 0+00. Precise locations of the tops of each profile in northing and easting were determined later by the CENWW surveyors (see Section 4.5 Site mapping and surveying). All profiles referenced the top of the near-vertical bank at the edge of the terrace as the top of profile (0 cm depth).

4.3 Profile preparation and sediment screening

Preparation of profiles and screening of sediments removed during preparation were accomplished jointly by members of the WES/CENWW team and the CTUIR ARPA-permit team. Both sides of each profile were delineated by a length of 1-in. I.D. PVC pipe driven into the base and secured at the top and bottom of the bank with short sections of rebar driven into the bank. Depth from the top of the bank was marked in 20-cm intervals with colored markers to facilitate profile descriptions. Each profile was approximately 50 cm wide. The height of the bank, and therefore of the profiles, varied from 120 to 220 cm (Figure 6).

The white polyvinyl chloride (PVC) pipe marked the boundaries of the profiles so that they were easy to see in low light and in photographs. Where profiles were stepped to accommodate the natural terracing of the bank, multiple shorter lengths of pipe were secured individually with rebar (Figures 4 and 7). The team measured the original slope of each profile by the vertical (plumb), horizontal, and slant distances from the top of the bank to the foot of the profile. Profile of the unmodified bank was documented in 20-cm increments prior to the removal of sediments back to a near-vertical face.

After each profile was marked and documented, a WES geologist using a hand trowel cleared the profile by removing sediments directly into buckets for each 20-cm increment downward from the top of the bank. Clearing of most

20-cm intervals required screening of several buckets of sediment. Each bucketful of sediment was weighed and screened (Figure 8) by senior cultural resource technicians from the CTUIR ARPA-permit group. Their experience was in continuous use as they felt the sediment on the screens with their hands and described all materials audibly to the WES and other archaeologists throughout the process (Figure 9). Double screens of 1/8-in. and 1/4-in. mesh were used for 78% of the sediment processed. For the other 22% when large amounts of wet sediment caused an unacceptable backlog for the screeners, 1/4-in. mesh was used alone, and only after control samples were weighed and screened through 1/8-in.-mesh screens. The most obviously wet sediments were in the lowest intervals of the profile, below the layer associated with the remains, and without appreciable retention of materials on the screen.

The attendant archaeologists recorded a general description of the material screened in each interval including presence or absence of artifacts and ecofacts and changes in the amounts of geologic materials retained on the screen, for correlation with geologic profile descriptions (see Section 4.4 Geologic description of profiles). All geologic materials greater than 1/4-in. in size were bagged and labeled by 20-cm interval, and packed as profile groups for shipment to WES. Ecofacts were bagged separately and their provenance was recorded. The few artifacts encountered were described and photographed, but not removed from the site. The minimal archaeologic survey conducted during this study is described in Section 6.8 and Appendix C.

4.4 Geologic description of profiles

Use of PVC pipe to delineate profiles provided a framework to monitor the intervals being screened and the depth from the terrace surface of each layer or feature described. Measured PVC pipe was left in place for the duration of the study so that all team members had the opportunity to visit and revisit each profile as they described, discussed, and compared features among the 12 locations. The freshly trowelled faces of bank sediment were relatively free of the effects of frost action and overbank sediment transport.

WES geologists generated descriptions at each profile, identifying sedimentary units from the top of the terrace downward. Units were distinguished on the basis of sediment type, texture, particle size, color (using a standard Munsell Color Chart), textural and structural characteristics, abundance of secondary mineral concretions or other evidence of post-depositional geochemical alteration, presence of paleosols, and other geologic parameters. Descriptive logs of each profile are in Appendix D. Unit thicknesses and depths to contacts between layers were corrected for the angle of the exposure, using the plumb, horizontal, and set-back angle lengths recorded in the field.

A soil scientist from the Natural Resource Conservation Service (U.S. Department of Agriculture) participated as a WES team member. He provided

detailed soil descriptions of profiles 005 and 054 and described and interpreted site geomorphology from the perspective of soil science. His report is included as Appendix E, and contributed to the team's interpretation of the stratigraphic and geomorphic setting of the study area. The WES team also collected samples at 10-cm intervals from selected profiles to be archived for grain-size analyses or detailed petrographic study should the need arise.

4.5 Site mapping and surveying

Prior to Phase Two geologic investigations, surveyors from CENWW established a baseline with stationing along the 350-m study reach. Bank profiles and other critical locations were referenced approximately to the stationing when they were defined by the study team. Then these locations were recorded precisely in Washington State Plane coordinates by the survey crew. CENWW prepared a map of the 350-m study reach showing locations of the waterline and treeline, general topographic contours, survey baseline, and core and profile locations at a scale of 1 in. = 40 ft (conversion factors on p xiii). A second map (1 in. = 10 ft) covers an area approximately 75 by 22 m (250 by 75 ft) between 25 and 100 m east of the zero point (between stations 0+25 and 1+00) in the vicinity of the discovery site. This map shows 6-in. ground contours, breaks in slope, the top of the bank, and the waterline, with contours extending from about 6.5 m south of the edge of the terrace and a similar distance into the reservoir. The CENWW maps are in Appendix F.

4.6 Geophysical survey

WES research teams have experienced success using geophysical surveys in other studies to locate buried items including cultural resources at military bases and on other Federal lands (Llopis and Sharp 1997; Butler, Simms, and Cook 1994; Simms 1996; Butler, Llopis, and Briuer 1993). CH2M Hill Hanford Company of Richland, WA performed a limited geophysical survey during Phase Two to test the usefulness of certain geophysical tools in shallow, fine-grained, saturated sediments. They used ground-penetrating radar (GPR) to survey an area of 5 m by 25 m on the beach below (north of) the vertical bank and a single line along the terrace edge, on a 1-by-2-m grid. CH2M Hill used a GSSI Sir-10A Plus GPR unit with 500 MHz antenna (Model 5103) and 300 MHz antenna (Model 3105 AP). Although this was a very limited study, it provided a basis for evaluating the method's effectiveness in detecting and delineating buried artifacts, areas of disturbed soil, or strata under the exposed sediments. The report provided by CH2M Hill is provided in Appendix G, and its implications are discussed in Section 6.7 of this report. These data will provide a baseline for potential future geophysical investigations of the Columbia Park site.

The lower reaches of the site, from the saturated sediments at the variable water line up to the base of the terrace (bottom of the bank line), were given

greatest priority in the geophysical survey. It was assumed that site protection might limit or prevent access to these sediments in the future. Secondary emphasis was given to a limited investigation of the terrace surface. To assure site mapping consistency, the geophysical grid was tied to the overall site grid by CENWW surveyors. Saturated sediments, such as those exposed when the pool level was dropped, are generally known to be non-conducive to GPR investigation. Nevertheless, this was an opportunity to acquire wet-zone data that would be relevant to the question of radar signal attenuation. Wet-zone data could be compared with those taken from drier strata of the terrace.

4.7 Soil cores

The WES team collected 10 soil cores using a Vibracore sampler. This device uses the principle of liquefaction in fine-grained sediments where displacement of the soil particles allows penetration of the core barrel (Smith, Dunbar, and Britsch 1986). Vibrations in the sampling pipe and the weight of the attached vibrator cause the pipe to penetrate downward, forcing the soil into the pipe. The device consists of a hydraulically actuated vibrator (used commercially for concrete placement) modified to clamp onto standard 3-in. I.D. thin-walled aluminum irrigation pipe. Other components of the equipment are a gasoline-powered hydraulic pump delivering fluid to the vibrator via a flexible hose, an aluminum tripod with winch, and a base plate (Figure 10). The bottom of the sampling pipe is cut at a 45-degree angle to provide a smooth cutting edge.

The WES selected the Vibracore device for the Kennewick study based on past successes with its application to similar investigations in water-saturated sediments. WES teams have used the Vibracore sampling technique in several investigations to provide samples for describing and interpreting environments of deposition, for dating of strata or cultural features, and for characterizing the paleogeomorphology of an area. Geomorphic mapping of the Davis Pond fresh-water-diversion study area in southeast Louisiana (Britsch and Dunbar 1990) used the Vibracore sampling to provide data for stratigraphic correlation, radiocarbon dating, biostratigraphic analysis of subsurface sediments, and X-radiographic analysis to identify the deltaic environments present in the subsurface. In a similar study, the Vibracore method provided subsurface data to establish the geomorphic framework for cultural resources studies in the opening of the Shreveport, LA, to Daingerfield, TX, segment of the Red River Waterway (Albertson and Dunbar 1993).

Analysis of Vibracore samples also helped delineate 11 separate fluvial, paludal, and lacustrine geomorphic environments in the Atchafalaya Basin of southeast Louisiana (Smith, Dunbar, and Britsch 1986). Stratigraphic and biostratigraphic analyses of 261 cores taken during that study provided detail of lithology, texture, color, relative moisture content, sedimentologic structures, relative organic content, estimates of salinity, and a determination of

depositional environments. Based on these successes, the WES team decided to apply the Vibracore device to the Kennewick site study to recover datable sediments and define stratigraphy below the exposed bank (Figure 10). The device used in Kennewick was loaned to the WES for this study by the USAE District, New Orleans.

Sections of irrigation pipe 10 ft long were pushed to refusal at five locations along the study reach. Two cores were taken at each location. Before extracting the sample tube from the ground, the team measured the amount of compaction in the soil sample column caused by vibration. The small measured compaction factors, usually 10% or less of core length, indicated good core recovery. Rubber-sealed packers were secured in the open tube end prior to withdrawal to provide a vacuum and maintain the sediment in the tube. Upon withdrawal of the sample tube from the ground, the ends of the tube were sealed with packers and tape, the tubes were labeled, assigned Columbia Park Core, or CPC, numbers giving the station location where the core was taken, and stored indoors at the CENWW Pasco sign shop. One of each pair of cores was subsequently transported to the WES for analysis. The second set was made available to the WSU ARPA team. Most of the cores were obtained from saturated soils lying at elevations below pool level of the reservoir (Figure 11). CPC 059.5, which was taken from the lower terrace of the beach, provided sediment samples from the interval between the base of the profile and CPC 054 so there was no break in the stratigraphic sequence.

Vibracore locations are shown in Appendix F. Some core locations are shown on a topographic map of the immediate vicinity of the remains discovery (Figure 12). Other core locations can be associated by stationing with the profile locations (Figure 5). Sample lengths varied from about 18 in. to 9.5 ft. Core logs are included in Appendix D. Depths shown in the core logs are not corrected for compaction, because compaction was minor and usually is not uniformly distributed throughout a core.

5 Laboratory analyses

5.1 Sediment samples

A large number of small-volume samples was collected at the study area during December and returned to the WES. These included samples from each identifiable stratum in each profile, and extra samples collected from special features between profiles. Samples representing apparent reworked volcanic ash (tephra) were collected from several profiles for petrographic verification. Other sample sets were the screening samples from each 20-cm screened interval in every profile, and the sediments collected in cores. Analyses of the particle size and mineralogy of each of these several hundred samples was outside the scope of this project. Instead, samples were selected from this suite for specific analyses targeted to address the critical questions in interpretation of depositional environments, geomorphic features, chronology, and correlation of strata within the study area. Samples not analyzed are archived in the WES Geotechnical Laboratory.

5.2 Analyses conducted

Targeted analyses were performed to provide absolute dates of key horizons, and to provide a basis for interpretation of the environments of deposition represented by the soils, soil stratigraphy, and continuity of soil strata within the study reach. Tests and analyses performed at the WES included the following.

5.2.1 Grain size and size-distribution parameters and soil classification were determined by optical and mechanical methods for selected profile and core samples. This was done to verify the soil types identified in the field. Examples of analyses are included in Appendix D.

5.2.2 Percentage of organic carbon in selected samples from profiles and cores was quantified by a test for loss of sediment mass on combustion at 550° C, again as a numerical basis for comparing strata. This test determined if there was adequate carbon in the soils to make them candidates for age dating.

5.2.3 Weights of material retained on screens were tabulated and recalculated as percentages of total sediment screened for each profile interval.

5.2.4 pH was measured for representative profile and core samples, using a modification of the standard method for determining pH of soils, American Society for Testing and Materials (ASTM) D4972-95. This allowed a comparison of one important chemical parameter of the sediments above and below the water line to confirm field observations of abundance of carbonate minerals.

5.2.5 Reactivity of core sediments to hydrochloric acid was noted, again as an indicator of the presence of calcium carbonate. This provided data to be compared with similar tests conducted at the field site on sediments in each layer of the profiles.

5.2.6 Detailed descriptive logs of cores returned to WES recorded the same parameters that had been recorded for profiles in the field (soil type, color, contacts, bedding characteristics, etc.).

5.2.7 Dissolution in hydrochloric acid provided approximate calcium carbonate content of concretions.

5.2.8 Mineral and chemical compositions of representative samples of tephra and concretions were determined by X-ray powder diffraction (XRD) and X-ray fluorescence performed during scanning electron microscopy (SEM). SEM images of tephra also were taken.

5.2.9 Mineralogy of sand samples from the lower portion of cores was determined by XRD, magnetic separation, and microscopy. The lower core materials had characteristics unlike any other sediment samples, and necessitated special analysis.

5.2.10 Petrographic characterization and mineral identification of various soil and tephra samples were accomplished using binocular microscopes for both oil-mounted grains in transmitted polarized light and washed dry-mounted grains in reflected non-polarized light.

5.3 Verification of tephra

To supplement the WES analyses, a sample of the most continuous layer of tephra, near CPP 334, was sent to the United States Geological Survey (USGS) Tephrochronology Laboratory in Menlo Park, CA. This Federal laboratory is world renowned for its expertise in mineralogic and chemical identification of tephra samples. It maintains a reference data base from hundreds of analyses of tephra samples collected throughout the geographic area affected by each major volcanic event. The WES team considered this necessary in the Federal interest, for independent verification of field identification of the Mazama ash observed by the WES team during Phase One investigations. The USGS report on

analysis of the tephra sample, describing methods used, is included as Appendix H.

5.4 Radiocarbon dating

Two ecofacts (shell samples) were sent to Beta Analytic, Inc., in Miami, FL, for age dating using accelerator mass spectrometry (AMS) and conventional techniques. Their report, with information about methods used, is included as Appendix I. One shell sample was taken from CPP 005 between 60 and 80 cm below the terrace surface (top of profile). The second shell sample was from a midden east of CPP 200 at 60 to 65 cm below the terrace surface (see Section 6.8 Archaeological survey). Both shell samples were taken from the exposed bank face. Four of the sediment samples determined to have an adequate amount of carbon were sent to the USGS laboratory in Reston, Virginia, for AMS dating. Results of the soil analyses also are included in Appendix I. All dated soil samples were taken from cores. Source locations for samples dated are shown on Figure 13. Limitations and sources of error for dating shells are described by Huckleberry, Stafford, and Chatters (1998). AMS techniques and potential sources of error are described by Stafford et al. (1991).

5.5 X-radiography of soils

To assist in interpretation of the depositional environments indicated in the cores, four Vibracores were imaged by X-radiography at Parkview Hospital in Vicksburg, MS. Radiographic techniques reveal subtle depositional and structural details not evident by routine visual examination and logging of soil cores. WES experience has found X-ray techniques to be ideally suited to distinguishing sedimentary stratigraphy in fluvial and backswamp sediments that appear at first to be homogeneous (Britsch and Dunbar 1990).

Samples for radiography were prepared at the WES. This preparation involved splitting a 3-in.-diameter core in half along its longitudinal axis, then cutting a 1-cm thick slab of sediment the full length of the cut face of one half. Each 1-cm-thick slab was supported by cardboard to prevent sample bending and breakage, and wrapped in plastic to preserve soil moisture and deter drying shrinkage and cracking. The upper and lower half of each prepared core slab was imaged separately, for a total of eight radiographs from four cores. In the imaging process, the 1-cm-thick slab is placed onto X-ray film and exposed to radiation. X-rays are absorbed differentially by the soil depending on variations in density, mineralogic composition, content of organic material, and sediment structure. Absorption patterns are registered on the X-ray film as an image from which an experienced geologist can recognize bedding, gaps in sedimentation, and interpret environment of deposition.

6 Results of laboratory and other analyses

The following sections describe the results of analyses of field data and of laboratory tests and analyses performed following on-site activities. Many samples collected in the field are archived at the WES and remain available for additional analyses to address specific questions in the future.

6.1 Stratigraphic relationships from cores and profiles

Detailed review of field logs of the bank profiles and examination of cores in the laboratory revealed features within the soil column that could be distinguished in specific strata and correlated over part or all of the study reach. Samples from core strata, of deeper and presumably older sediments than those in the exposed bank and in the profiles, were generally more uniform in texture than were the upper (bank) strata and lacked macroscopic concretions. Sediments cored in the western (upstream) half of the study reach were generally finer grained and more uniform in grain size than were sediments cored in the eastern (downstream) part, near the discovery site of the remains.

Compilation of core and profile logs into stratigraphic cross sections confirmed the presence of a persistent and correlatable horizon above which concretions are common to abundant. Below this horizon concretions were very rare or absent (Figure 13 and section B-B', Figure 5). This abrupt horizon lies at an elevation of approximately 343 ft NGVD[3], representing a depth of about 100 to 120 cm below the top of the bank which is easy to correlate along the study reach. The cross section also identifies a unit of coarser sediments in the upper portion of the bank. The upper unit defined by the coarser texture is sand to sandy loam and in most profiles is directly underlain by, or includes at its base, a discontinuous layer of volcanic ash (tephra). The tephra was best recognized in the field at the west end of the study site near CPP 334 where it was a laterally continuous layer about 20 cm thick. This continuous exposure of tephra is shown in Figure 14.

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[3] National Geodetic Vertical Datum, which corresponds to mean sea level (MSL).

Recognition of correlatable strata or horizons permits extrapolation of age dates obtained from features or artifacts found at any point within the study reach to the location and sedimentary layer associated with the ancient remains. A generalized stratigraphic column for the study site, delineating correlatable units, is shown in Figure 15. Unit I is modern topsoil. Unit II is the upper sandy layer, underlain in most profiles by recognizable volcanic ash or the ash mixed with other sediments (Unit III). Unit IV also was recognizable in the field as being finer grained than Unit II, and having abundant calcareous concretions. Its finer grain size made it denser and the concretions made it somewhat harder than was Unit II, and somewhat more resistant to erosion than was Unit II in some profiles. Unit IV forms the minimal but recognizable ledges shown in Figures 4 and 7. In CPP 334, a continuous layer of chemical concretion composed of calcite and silica was immediately below the Unit III tephra. The tephra was partially cemented by apparently the same chemical material. The tephra and attached calcrete/silcrete layer together formed a ledge, below which Unit IV was preferentially removed by erosion. Thus, Unit IV is a weak ledge-forming unit in much of the study area but is preferentially eroded near the western end of the study site. Units I through V are shown between CPP 080 and CPP 054 in Figure 16, and near CPP 334 in Figure 14.

The upper boundary of Unit V was defined by absence of concretions and a finer grain size than Unit IV (an increase in clay-sized material). Unit V was best observed in the cores, where it continued well below the reservoir level. Unit VI, identified from two cores, had the best preserved bedding structure seen in any unit, had the coarsest grain size encountered in the study area, and contained abundant opaque and heavy minerals.

Units I through V were correlated through all profiles with a few exceptions. The tephra layer was 20 cm thick in CPP 334 and present but discontinuous at most other profiles. Through the central portion of the study area, concretions are so abundant at the top of Unit IV that it is a distinct ledge-forming unit. Its fabric is concretion supported rather than grain supported (CPP 125, 166, 200). In CPP 005, Unit IV had no concretions, and the volcanic ash of Unit III was represented only as a few reworked tephra clasts. Remnants of a paleosol, a buried soil horizon dating from a prehistoric episode of soil formation, were recognized in the position of Unit III in CPP 005. In other profiles the paleosol surface was just above Unit IV where concretions are extremely abundant.

Correlation of Units III and IV among profiles is shown by the cross sections in Figure 13. This section (indicated as B-B' on Figure 5) reveals how the strata at each profile are related, and how each unit changes in thickness from one profile to the next. Figure 17 shows the correlation among profiles and cores in the immediate vicinity of the discovery site (section A-A' from Figure 12). Profile depths are corrected to elevation. The resultant stratigraphic column documented in this study extends from the terrace surface to about 200 cm below the usual reservoir pool level, a combined thickness of nearly 4.5 m. To

our knowledge, this is the first time these sediments have been cored for geologic correlation with the sedimentary units of the terrace.

6.2 Results of determinative mineral and chemical analyses

Petrographic analyses of samples taken from Unit III in most profiles confirmed our field identification of the light-colored material from this layer as tephra, even where it was discontinuous and mixed with other sediments. The petrographic analysis was essential for confirming the presence of this correlatable unit at a comparable depth throughout the length of the study site. Figure 18a is an image of the tephra from SEM, showing typical conchoidal fracture of volcanic glass. Figure 18b is a photograph of the tephra taken in polarized transmitted light, showing the expected fluffy texture and optical isotropy. These features were recognizable in Unit III samples collected throughout the site. Various feldspars and pyroxenes were recognized in petrographic study of the tephra samples, and both calcite and quartz also were identified in the samples by X-ray powder diffraction.

The USGS analysis of a sample collected from the continuous portion of Unit III near CPP 334 confirmed the field identification of this particular tephra as the Mazama ash, from the volcanic eruption of Mount Mazama approximately 6,700 yr B.P. The letter report from the USGS Tephrochronology Laboratory is included as Appendix H. Summarizing from that report, the tephra submitted for analysis consists of about 65% glass shards, 10% volcanic lithic grains and other more rounded grains of detrital material, about 20% plagioclase feldspars, and about 5% heavy and opaque minerals including augite, hypersthene, hornblende, and magnetite. Surfaces of angular crystalline mineral grains were coated with glass or enclosed in glass shards, indicating that they crystallized from the magma prior to eruption. This suite of minerals is essentially the same as Mazama ash minerals reported in previous published studies (Sarna-Wojcicki, Champion, and Davis 1983; Davis 1978). The USGS report comments that the calcite and quartz identified in the sample by XRD are likely to be either from non-ash sediments or authigenic cementing by mineral precipitation from ground water. It also noted that the sample was bioturbated, that is, its fabric and internal structure had been disturbed by plants and/or animals.

The USGS Tephrochronology Laboratory has a reference file of about 4,100 analyses from tephra samples collected in the U.S., of which 94 are Mazama ash. Table 1 shows the remarkable agreement between the analysis of the Kennewick sample and an average composition from the USGS reference file. No other known layers of ash have this composition.

Sample	SiO2	A12O3	Fe2O3	MgO	MnO	CaO	TiO2	Na2O	K2O	Total,R
Kennewick site tephra	72.83	14.60	2.07	0.44	0.04	1.55	0.41	5.33	2.74	100.01
ref. Mazama ash, avg of 94 samples	72.79	14.65	2.12	0.46	0.05	1.61	0.42	5.19	2.71	100.00

Table 1. Comparison of chemical analyses of Kennewick site tephra and USGS reference data for Mazama ash

6.3 Other data for mineralogy and chemical composition of sediments

Magnetite was detected qualitatively by magnetic separation on trace quantities in several subsamples. It was most common in samples from Unit VI, and also easily detected in some Unit II samples. It was very rare in Unit IV samples, including concretions.

Samples of Unit II sediments from CPP 166 were washed in distilled water to remove clay-sized material prior to examination by conventional microscopy. This technique revealed two different populations of quartz grains. Smaller, more angular grains are clear and have recognizable crystal faces and fresh-looking surfaces. These are typical of alluvial grains. Larger quartz grains are nearly spherical, with no crystal faces visible because the surfaces are covered with fine scratches known as frosting. Frosted quartz grains typify wind-blown sands. Varying amounts of dark and opaque minerals also are present, including garnets, pyroxenes, and magnetite. There are few lithic fragments in the sands, that is, most of the particles have been physically reduced to individual crystals instead of multiple crystals or minerals remaining attached as they were in the source rock, with the possible exception of some finely crystalline basalt fragments.

X-ray fluorescence (XRF) of concretions from Unit IV confirmed field observations that both calcium carbonate and silica were present. Concretions from the eastern part of the study area contained minimal sediment particles and minimal silica. Water-washed concretions from the discovery site were almost completely dissolved in hydrochloric acid, leaving only very small amounts of fine sediment. This indicates that the concretions are composed primarily of calcium carbonate. Concretions from the west end of the site contained more silica. The concretion layer beneath the continuous tephra bed at the west end of the site contains both calcium carbonate and silica. These differences have been observed but not quantified. The presence of both calcium carbonate and silica in the concretion layer immediately beneath the tephra is consistent with cementing by these minerals observed by WES and by the USGS Tephrochronology Laboratory.

Sand from Unit VI was the coarsest sediment encountered in the study area. This sand also contained a larger proportion of heavy and opaque minerals in distinctly recognizable layers. Multiple thin layers of sand with abundant heavy minerals were interbedded with finer grained layers in the lower portion of CPC 044 (see Figure 17). This indicates short-term depositional cycles, a phenomenon that was unique to Unit VI. A similar sequence was encountered at the bottom of CPC 054, which did not extend as deep into the sediments as CPC 044. Huckleberry et al. (1998) also observed this banding in the lower portions of the duplicate cores they studied.

Samples taken from the thin interlayered strata of Unit VI were observed with a binocular microscope as grain mounts in transmitted light. These thin strata, with a preponderance of dark and opaque minerals, appeared to have a larger median grain size and better sorting than the finger grained units above them. Pale green grains of the mineral diopside were common, as were clear (not frosted) quartz grains and feldspars showing crystalline twinning. Limited XRD analyses indicated the presence of quartz, the feldspars albite and microcline, other igneous minerals such as diopside and muscovite, cristobalite (which is a high-temperature form of silica), and possibly a clay mineral (saponite) altered from volcanic glass. The absence of frosted grains, absence of garnets, minimal clay, and abundance of diopside, together with the coarser grain size, distinguished Unit VI from all of the overlying stratigraphic units.

6.4 Results of other laboratory tests and observations

Several simple laboratory tests performed at WES on selected samples provided data on characteristics of the soil or other components of the profiles and cores. Four soil samples of less than 100 gm mass from each of CPP 200, CPC 200, CPP 093, and CPC 054 were placed in water suspension and the pH of the suspension measured for each. The purpose was to compare sediment pH above and below the water table. Sediments below the water table were acidic (low pH) and the sediments above the water level and within the concretionary layer, Unit IV, were alkaline (high pH) (see Table 2).

	Sample ID	Approx Elev (ft)	pH	Approx wt sample (gm)
Concretionary layer	CPP 093	344	7-1/2 to 8	62.5
	CPP 200	344.5	8	25.5
Below concretionary layer	CPC 054	337.5	5-1/2 to 6	53
	CPC 200	339.5	5-1/2 to 6	32.8

Table 2. pH values of selected soil samples within and below the concretionary layer

The archaeologists and technicians who weighed and screened sediment had the impression that the buckets of sediments from the lower part of the bank profiles (usually Unit V) had a higher water content than soils in other layers. To determine an approximate water content of sediments at the base of the terrace, a specimen of sediment was taken from core CPC 059.5 at a depth of 119 to 130 cm. It was dried at a temperature of about 100° C, and its water content was calculated to be 27%. This provided an approximate value to use in any quantitative comparisons of amount of material screened from each interval. The brittleness and other characteristics of the sediment when dry were consistent with the high silt content and low clay content in the sediment described in the field.

The WES and CTUIR archaeologists and technicians had weighed material removed from the 12 profiles, screened the sediments through 1/8-in. mesh, and retained all materials that were coarser than 1/4 in. The retained materials were returned to the WES for further analysis and archiving. Material retained on the screens was primarily the concretions described in section 6.3. Weights of material retained on screens from each 20-cm sampling increment, the total weight of soil screened in each 20-cm increment, and the percentage by weight of retained material are compiled in Table 3. These data were used to confirm field measurements and for correlation of Unit IV across the site. For intervals not reported in Table 3, no material was retained on the 1/4-in. screen.

6.5 Radiography

Images from radiography of the core samples revealed that the bioturbation observed in profiles in the field (see Appendix D) also had affected the sediments now below the water level. However, the images did reveal some core intervals where stratigraphic details are still preserved. These intervals, especially near the bottoms of cores, indicate moderately rapid burial with enough vertical accretion of new sediment to protect the underlying strata from post-depositional organic activity that destroys bedding structure. Heavy minerals in coarser sand were readily identified in the radiographs and revealed fine laminations. The images revealed no distinctive breaks in sedimentation and no extreme flood deposits such as coarse sands and gravels. Figure 19 shows prints from radiographs of CPC 044, lower section. Bioturbated areas appear gray and without visible structure. Heavy minerals appear in visible dark bands with laminae preserved. Fine cross bedding also was visible in CPC 054 near the bottom of the core. Interpretation of the radiographs defined a fluvial depositional environment for the discovery-site sediments.

Table 3. Weights of material retained on screen

Profile #	Depth Interval (cm)	Weight Retained (gms)	Weight Retained (lbs)	Total Weight (lbs)	% Retained
CPP 005	0 - 20	0.0	0.0	1.0	0.0
	20 - 40	0.0	0.0	2.0	0.0
	40 - 60	0.8	.0018	6.0	0.03
	60 - 80	5.0	.0110	17.0	0.06
CPP 044	0 - 20	7.9	.0174	25.0	0.07
	40 - 60	1.9	.0042	10.0	0.04
	60 - 80	104.8	.2310	14.0	1.65
	80 - 100	26.9	.0593	18.0	0.33
	120 - 140	12.0	.0265	34.0	0.08
	140 - 160	8.6	.0190	34.0	0.06
	160 - 180	150.3	.3313	89.0	0.37
	180 - 200	3.3	.0073	15.0	0.04
CPP 054	0 - 20	0.1	.0002	9.0	0.00
	60 - 80	591.2	1.3034	44.0	2.96
	120 - 140	4.7	.0104	9.0	0.14
	140 - 160	2.1	.0005	20.0	0.00
	165 - 185	4.9	.0108	11.0	0.10
	185 - 205	50.8	.1120	21.0	0.53
CPP 080	60 - 80	4.7	.0104	3.0	0.35
	80 - 100	180.7	.3984	10.0	3.98
	100 - 120	87.0	.1918	11.0	1.74
	120 - 140	36.1	.0796	12.0	0.66
	140 - 160	905.6	1.9965	35.0	5.70
	160 - 180	145.6	.3210	15.0	2.14
CPP 093	0 - 20	0.0	0.0	13.0	0.0
	40 - 60	14.8	.0326	9.0	0.36
	60 - 80	61.3	.1351	8.0	1.69
	80 - 100	94.7	.2088	11.0	1.90
	100 - 120	24.6	.0542	9.0	0.60
	120 - 140	78.6	.1733	21.0	0.83
CPP 125	0 - 20	6.9	.0152	3.0	0.50
	20 - 40	80.6	.1777	2.5	7.10
	40 - 60	21.1	.0465	2.0	2.33

Profile #	Depth Interval (cm)	Weight Retained (gms)	Weight Retained (lbs)	Total Weight (lbs)	% Retained
	60 - 80	105.0	.2315	9.5	2.44
	100 - 120	25.6	.0564	5.0	1.13
	120 - 140	1.3	.0029	6.0	0.05
	140 - 160	1.4	.0031	14.0	0.02
CPP 166	0 - 20	0.3	.0007	9.0	0.01
	20 - 40	0.2	.0004	4.0	0.01
	40 - 60	7.2	.0159	13.0	0.12
	60 - 80	357.3	.7877	21.0	3.75
	140 - 160	0.3	.0007	45.0	0.00
CPP 200	40 - 60	171.2	.3774	10.0	3.77
	60 - 80	204.5	.4508	12.0	3.76
	80 - 100	131.2	.2892	29.0	1.00
	100 - 120	261.5	.5765	8.0	7.21
	140 - 160	0.0	0.0	8.0	0.00
CPP 233	20 - 40	0.0	0.0	3.0	0.00
	60 - 80	175.9	.3878	5.0	7.76
	80 - 100	287.8	.6345	6.0	10.58
	100 - 120	21.9	.0483	5.0	0.97
CPP 268	0 - 20	51.7	.1140	5.0	2.28
	20 - 40	178.5	.3935	10.0	3.94
	40 - 60	27.1	.0597	7.0	0.85
	60 - 80	16.6	.0366	5.0	0.73
	80 - 100	19.9	.0439	7.0	0.63
	140 - 160	8.2	.0181	6.0	0.30
CPP 296	0 - 20	7.2	.0159	4.0	0.40
	60 - 80	118.8	.2619	4.0	6.55
	80 - 100	216.4	.4771	11.0	4.34
	100 - 120	88.8	.1958	9.5	2.06
	120 - 140	227.7	.5020	14.0	3.59
	140 - 155	39.0	.0860	5.0	1.72
CPP 334	120 - 140	0.7	.0015	40.0	0.00
	140 - 165	3.4	.0075	73.0	0.01

6.6 Radiometric dates and carbon content of sediments

Age dates for the two shell samples are similar. The shell sample taken from an apparent midden east of CPP 200 (see Figure 13), at a depth of 60 to 65 cm, indicates an age of 6,090 ± 80 yr B.P. Age of the shell sample taken from CPP 005 at 60 to 80 cm depth gave an age of 6,510 ± 60 yr B.P. Details of analytical methods and calibration are in Appendix I. Both of these samples were taken from the horizon between Units II and IV at locations where Unit III was discontinuous or essentially missing. That is, both samples were taken close above Unit IV.

Four sediment samples were submitted for analysis from CPC 059.5, once it was determined that the sediments had adequate carbon for radiometric dating (see below). One sample was from Unit IV, in the portion of the core that overlaps with CPP 054 (see Figure 17). For reasons explained in Section 7.2, we assume that the remains were eroded from Unit IV. A sample was taken to determine the absolute age of some of the sediments in that unit. Samples taken from lower in the core were expected to indicate whether or not the sediments had been disturbed, and to provide a geologic date for the landform. Carbon content of samples from CPC 059.5 was determined as a basis for deciding if there would be adequate benefit from attempting AMS dating of the sediments themselves. Carbon content for all samples was between 1.5 and 2.5 %. This was considered to be enough carbon to justify sending samples for age dating.

The first two sediment samples submitted for AMS dating were from depths of 10 to 20 cm and 190 to 200 cm in core CPC 059.5. Figures 13 and 17 show the relative positions of the dated samples. The sample from 10 to 20 cm (approximate elevation 342.3 ft MSL) provided a radiocarbon age of 9,010 yr B.P. ± 50 yr at the bottom of Unit IV. The sample from 190 to 200 cm (336.8 ft MSL) provided a date of 15, 330 yr B.P. ± 60 yr. Two additional sediment samples from depths in core CPC 059.5 of 130 to 138 cm (338.6 ft MSL) and 220 to 229 cm (335.7 ft MSL) were subsequently submitted for dating. The sample from 130 to 138 cm yielded an age of 12,460 yr B.P. ± 50 yr and the sample from 220 to 229 cm an age of 14,560 yr B.P. ± 50 yr. Evaluation of potential sources of error in these dates is outside the scope of this study, and is discussed by Stafford et al. (1991).

6.7 Geophysical survey

The limited non-intrusive geophysical survey was conducted to search for any definite anomalies in the sediments between the edge of the terrace and the reservoir during the time the pool level was low. Anomalies could indicate discontinuities in deposition, or post-depositional disturbance of sediments, such as gravesites. The methods used, as described in Appendix G, were effective in finding very distinct items such as historic metal objects along the beach. Using GPR in saturated sediments, the effective depth of investigation was less than

1 m. Results of the one transect along the terrace edge were more promising, with effective depth of 2 m. It may be possible to detect more subtle changes in sediment characteristics in the unsaturated terrace sediments. The limited survey did not detect or suggest the presence of gravesites. Survey results show no large contrasts between sedimentary layers in the shallow subsurface below (north of) the terrace. The geophysical data are consistent with the record of fairly uniform sedimentation in a broad quiet-water area as documented in the cores.

6.8 Archaeological survey

Most of the particles retained on 1/4-in. mesh during screening were concretions formed from pedogenic (soil-forming) processes. All non-pedogenic artifacts and ecofacts were separated from the bulk of the concretions for individual study. Most of these items were identified as ecofacts, such as shell and non-human bone fragments without direct evidence of human modification. Appendix C provides detailed descriptions of the recovery and characteristics of items identified in the archaeological survey.

Shell and charcoal fragments were recovered in place above Unit IV in CPP 005. A sample of shell taken from the top of the buried soil horizon in CPP 005 yielded an age date of 6,510 ± 80 yr B.P. (see Appendix I). A fragment of apparent fish bone found in place in the upper 20 cm of CPP 044 was considered too small for age dating, and potentially modern because of its near-surface location. Screening in CPP 080 yielded a fragment of burned mammal bone at 160 to 180 cm. This fragment was tested for its potential for age dating at the Radiocarbon Laboratory of the University of California, Riverside, but was too small and fire-damaged to be datable.

Shell fragments also were present in Unit II of CPP 166. More importantly, two basalt flakes were screened from the sediments at the base of the profile, at 160 cm depth. These were the only true artifacts separated from the soil during screening. Finding artifacts at the base of an exposure always poses the possibility that the artifacts may have eroded out of the exposure at some unknown higher stratigraphic level and were subsequently covered by soil at the toe of the bank. Geologists from WES and WSU agreed on-site that the sediments were in place, and probably not a slump feature from higher in the terrace. However, only a small amount of sediment was screened here, so the teams were not certain that the flakes came from intact sediments. If the flakes were in place, their stratigraphic position suggests that they may be even older than the ancient remains.

Screening CPP 200 yielded shell fragments in the intervals from 80 to 120 and 140 to 160 cm. About 3 m east of the profile, researchers found a large stratified shell midden, 35 to 50 cm down from the top of the bank. The midden was a lens of complete or nearly complete shells apparently of freshwater

mussels (see Appendix C). The WES team and several other archaeologist observers interpreted the shell layer as a midden, that is, shells accumulated during human activity, because of the size and overall geometry of the lens and its similarity to middens with associated artifacts elsewhere along the Columbia River. The age of a sample of shells from the midden was determined to be 6,090 ± 80 yr B.P. (Appendix I).

Shell fragments were screened from Unit II in CPP 233, and CPP 268 had flakes of carbonized material in Unit II. Screening at CPP 093 and CPP 125 revealed no artifacts or ecofacts.

Tribal observers and the WES archaeologist identified other artifacts near and between profiles, but not in place in the sediments. A tool scatter near the west end of the study area included flakes of basalt, quartz, and obsidian, and incomplete projectile points. A basalt unifacial core tool was found near CPP 005. These items are described more completely in Appendix C. Although these items could not be associated with any sedimentary unit, they do indicate prehistoric human activity at the site. The appearance of artifacts and ecofacts over the length of the study area becomes an important indicator of the cultural resources of the entire site, if one considers how small was the amount of sediment moved and screened during the study.

7 Interpretation of geologic setting

7.1 Introduction

Interpretations of the geologic setting of the study site are based on evaluation of the field data, laboratory analyses, and study of historic topographic maps and aerial photographs dating from 1930 through the 1990's.

7.2 The stratigraphic unit associated with the ancient remains

Throughout this report, the ancient remains found at the Kennewick site have been associated with Unit IV. This association represents the hypothesis that the remains were included in Unit IV sediments beginning soon after the death of this individual and continuing until 1996. When they were found, the remains were not in place in the sediments so their exact position relative to landform and stratigraphy is not known. No member of the WES team has seen or studied the remains. But other Corps of Engineers scientists have provided descriptive information from their observation of sediments still attached to the remains, and of sediments in the bags that previously held the remains and have been maintained with them. The sediments still attached to the remains have been described as being so extensive that they mask large areas of the bone surfaces. Individual concretions are present on some bone surfaces, and some individual bones apparently are connected in groups by larger cemented sediment masses (information from Michael Trimble and Ray Tracy, USACE archaeologists).

Based on the description of these concretions and hardened sediments associated with the remains, it can be inferred that the remains came from the stratigraphic unit with the most concretions, which is Unit IV. Concretions were present as lag deposits along the reservoir shoreline where they had been eroded out of Unit IV. These lag deposits accumulate because the individual concretions are particles too large to be transported easily by the river. The non-cemented fine-grained matrix washes away. Lag deposits of concretions were particularly noticeable between profiles 125 and 054 where the concretion clasts formed a gravelly surface at the water's edge. Screening of sediments along this portion of the study area also revealed fairly large quantities of concretionary

particles. This, too, is consistent with the hypothesis that the remains had been enclosed in Unit IV. Anecdotal evidence indicates that the remains were found in the water along the portion of the shoreline between approximately CPP 093 and CPP 054, where concretion lag deposits are most abundant. This suggests that the remains washed out of this very concretion-rich portion of the bank, an hypothesis consistent with the abundance of concretions and sediment still associated with the remains.

A question as important as the geologic age of the remains cannot be answered with only one line of scientific evidence. It should be possible to determine more closely the stratigraphic unit associated with the remains by study of the sediments stored with them and comparable study of sediments collected from the exposed bankline. Features such as Munsell color, concretion size and composition, amount of granular sediment in the concretions, mineralogy possibly including percentage of some opaque mineral, and composition and grain size distribution of the sediments still associated with the remains could be determined, and comparable data collected from study of the sediments from known depths and positions. The abundance of a trace mineral such as magnetite may be a useful indicator for matching sediments from the remains to a depth and location in the bank. Magnetite is more common in the samples studied from Unit VI and Unit II than it is in samples from Units III and IV. The amount of magnetite in the sediments still with the remains could be quantified and should match fairly closely the amount of magnetite in the associated sedimentary unit. In addition, Unit III is tephra presumed to be younger than the remains, so there should be no Mazama tephra in the sediments with the remains. Petrographic study also may reveal that the frosted and rounded grains of quartz observed in Unit II samples are unique to Unit II, and presumably should not be present in the sediments with the remains. There may be other unique mineral identifiers in these units that could be quantified by detailed petrographic study and matched to identifiers in the sediments attached to the remains.

The geochemical composition of concretionary material could be related or contrasted to the composition of Unit IV concretions from various profiles. Concretions from the downstream profiles (044 through 093) are largely calcium carbonate, while those from the upstream profiles (268 through 334) contain abundant silica. Volcanic glass is a major source of silica for pedogenic cementation in Holocene soils (Chadwick, Hendricks, and Nettleton 1989). The layer of tephra at the west end of the study site provided soluble silica to the groundwater and left its signature in the concretions in its immediate vicinity.

Distinctions in the amounts of a trace mineral, a certain grain type, and the composition of the cement from concretions together may provide chemical and mineralogic signatures to tie the remains to a certain sedimentary unit and a particular reach of the study area. Ages of the sediments in the bank could be determined by AMS techniques. This kind of multi-disciplinary study could

provide the information needed to relate the remains to a particular stratigraphic entity and age, in the same way the analysis of the tephra identifies it as Mazama ash. This would establish with more certainty the depth and area of the bank that held the remains prior to 1996.

The mechanism by which the remains were introduced into the water is discussed in section 7.6, Modern geomorphic processes.

7.3 Depositional environments and subsequent geologic processes

Sediments of Units I through V in the study area accumulated in fairly quiet, low-energy alluvial environments. An estimate of the rate of sediment deposition in the 4 m or so of the sediment column represented at the site in profiles and cores can be obtained from radiocarbon dates derived from five different elevations within the sediment column. Refer to Figure 13 for positions of dated sediments. Descending through the sediment column, dates were 6,700 yr B.P. for the Mazama tephra at elevation 345 ft, 9,010 yr B.P. for sediment at elevation 342.3 ft, 12,460 yr B.P. at elevation 338.6 ft, 15,330 yr B.P. at elevation 336.8 ft, and 14,560 yr B.P. at elevation 335.7 ft. Assuming a uniform sedimentation rate in each time increment, rates of 0.0012, 0.0011, and 0.0006 ft/yr are obtained for each increment, respectively.

The two oldest dates are problematic because the oldest date (>15,000 yr) was derived from sediments at a higher stratigraphic position than the level associated with the date of >14,000 yr. If the 15,330 yr B.P. date at elevation 336.8 ft is discarded and replaced with the 14,560 yr B.P. date at 335.7 ft, the rate for the lower increment is 0.0014 ft/yr, which is consistent with the other two rates of sedimentation and gives a net average rate of 0.4 mm/yr which is typical of quiet-water floodplain settings. This analysis implies that sedimentation was slow and relatively unchanged over a period of about 7,800 years. Note that this is a net rate of sediment accumulation and represents the balance between periods of deposition and periods of erosion. That is, the sediment profile is not a record of continuous accumulation, but only the intervals of sediment that escaped erosion to be preserved in the geologic record. The evidence of bioturbation and the presence of at least one recognizable ancient soil horizon indicate breaks in deposition. No dates were obtained for cored sediment below elevation 335.7 ft.

The mineral assemblage is consistent with sediment source areas in the Cascade Range and from reworked sediments within and surrounding the Pasco Basin. Transport and reworking along the way broke down rock fragments into their component mineral grains, and the resultant lack of lithic fragments also indicates slow accumulation. This transport also created fairly well-rounded and well-sorted sediments. A higher-energy depositional environment would be indicated by larger and more angular particles and less mature sediment assemblages with rock fragments. The depositional environment that resulted in

this sequence of fine-grained well-sorted sediments is a slackwater area associated with the Columbia River.

Sediments in the lower portions of cores (Unit VI) are the coarsest sediments in the sequence and contain the highest percentage of heavy minerals. These layers have cross-bedding and are not bioturbated, two features which are consistent with a higher-energy environment, rapid deposition, and no subaerial exposure. These sediments in Unit VI indicate a slightly higher-energy environment where finer and lighter grains were winnowed out. The cyclic nature of the coarser sediments suggests multiple fluctuations in water level.

Waitt (1980) describes cyclically interbedded sand and silt layers called rhythmites that are distributed widely in eastern Washington and originated from backflooding associated with temporary glacial lakes. He describes rhythmites at the margins of the Pasco Basin, usually overlying older flood gravels. At some locations, the sequence he describes consists of rythmites overlain by massive silt that locally contains Mazama tephra. Rhythmites are composed of reworked loess (windblown silt of glacial origin) and coarser, angular grains of minerals from igneous rocks. The appearance, mineralogy, and grain fabric of the interbedded sands and silts of Unit VI at the Kennewick site are similar to features described by Waitt for rhythmites. The apparent age of Unit VI, more than 15,000 years, and its position beneath a thick layer of silt with Mazama tephra, also are consistent with interpreting this unit as rhythmites.

Following deposition of Unit VI, fine-grained sediments accumulated almost continuously for a few thousand years, forming Units V and IV. These are typical slackwater deposits of a river system. The area would have been seasonally wet in most years, with emergent vegetation and tangled masses of plant roots. The consistently low percentage of carbon (usually less than 2%) indicates seasonal drying, typical of slackwater areas in semi-arid environments. A change in climate, basin geometry, or some other factor could have changed the dynamics of the river system, causing the slackwater area to dry out and deposition to cease long enough for soil to develop (pedogenesis of Unit IV).

The concretions in Unit IV are evidence of an emergent period. Extensive concretions such as these take a long time to form, by pedogenic processes during which groundwater dissolves mineral components which then re-precipitate when the evaporation rate is high (seasonal drying). In some profiles, the upper portion of Unit IV retains characteristics of the A and B soil horizons that developed during a period of emergence (see Appendix E), although only remnants of these horizons remain. In the Pasco Basin, the A and B horizons of paleosols commonly were flushed away by flooding, leaving lower portions of soil horizons in which calcic concretions were conspicuously present, and provided increased resistance to erosion (McDonald and Busacca 1992). In the study area, the presence of concretions in Unit IV is the major feature that distinguishes it from Unit V. The two units represent a continuation of one

depositional environment, but Unit IV is the upper portion that was changed subsequently by pedogenesis.

Soil formation was influenced by the chemical composition of the groundwater, which freely moved and concentrated calcium carbonate during alternating seasonal wetting and drying. This is similar to the processes described by Khadkikar et al. (1998) for a modern environment in which calcite concretions are forming. Aslan and Autin (1998) describe sediment profiles in the southern Mississippi River valley flood plain that share many features with sediments in the Kennewick study area. In both cases, it is difficult to recognize discrete paleosols because alternating periods of sedimentation and pedogenesis have been masked by bioturbation. Forest vegetation and borrowing fauna incorporate younger material downward, destroying primary sedimentary structures such as original lamination or cross-bedding. This combination of slow slackwater sedimentation and bioturbation welds individual layers together, resulting in the type of apparently structureless sediments observed in the profiles and cores of the Kennewick study. The composition of the resultant sediments reflects the lithology of the source areas. At the Kennewick site, sediments include components derived from diverse sources including loess, nearby basalt flows, and the igneous rocks of the Cascade Range to the west.

The Mazama ash appears in the profile in the upper part of or just above Unit IV. When it first fell, the ash would have been a thin veneer of very fluffy material, easily moved from high points by wind or surface water flow and collected in low or quiet areas. It appears to have been redeposited soon after the eruption, possibly by movement of surface water toward the river in a single rainfall event. A slackwater area is a perfect environment for collecting a thick layer of ash. Once wet, the ash would be prevented from becoming airborne again. This thick accumulation suggests that it remained covered by shallow water long enough to be covered by other sediments. There are grains of alluvial sediment in the ash layer. Although this is a minor component, the presence of some alluvial sediment even in the thickest and cleanest ash layer is consistent with its secondary accumulation in water.

The ash is co-mingled with uppermost Unit IV sediments. After the ashfall and after pedogenic processes had proceeded long enough to form the calcrete/silcrete layer, deposition of alluvial sediment resumed. The ash layer may have been thinner to the east in the study area and was extensively disturbed and reworked by bioturbation. Overlying the ash are Unit II sediments which contain more sand than did Unit IV. At least two sources of sand and two separate sedimentary processes contributed to Unit II. Both aeolian sand grains (frosted, spherical grains) and clear, less-rounded alluvial sand are present. Sand-sized fragments of shells also are present. This indicates a climate dry enough to provide blowing sand, but with enough water in the river system or at least seasonally to support aquatic life and form levee or overbank deposits.

The stratigraphic sequence at CPP 005 is distinct from the pattern established by the other profiles and suggests a local change in environment of deposition. The buried soil layer was present at the level of Unit III and was better preserved in 005 than it was in other profiles. But there were no concretions in what should have been Unit IV. This is the only profile that lacked concretions in Unit IV, and the only part of the bank in which concretions were not observed either in place or as a lag deposit along the water line. The presence of a paleosol without the concretions indicates that the area around CPP 005 was exposed to different pedogenic processes. Possibly these sediments represent an environment that was not emergent for the long time required to develop these concretions. Concretions of this type may take as long as 5,000 years to form (Wysocki letter report, Appendix E), but can form much more rapidly during the pedogenesis in semi-arid climates (Khadkikar et al. 1998).

The area at the east end of the study site may have been a depression, low enough that the upper paleosol layer (A and B horizons) was not removed when they were eroded away from the area to the west. There is also some indication of gleying below the paleosol, a feature that suggests the existence of anaerobic conditions at some time. The stratigraphic relationship of CPP 005 to the study area as a whole could not be established in a 2-dimensional study along the bank line. The preservation of the paleosol at this location suggests that this stratigraphic relationship could be very important. The paleosol is a potential prehistoric living surface, and could be associated with other cultural resources. Further study of the relationship between the environment at 005 and that of the other profiles could provide better understanding of the formation and subsequent exposure of the slackwater deposits that preserved the ancient remains.

7.4 Time sequence

Climate changes since 12,000 yr B.P. in the Pacific Northwest are well documented in published literature (Fulton et al. 1989; Barnosky 1984, 1985; Zoltai and Vitt 1990; Chatters and Hoover 1992). Several of these studies present evidence for drier conditions between 10,000 and 8,500 yr B.P., an increase in rainfall beginning at 8,500 yr B.P., and possibly the driest period of the Holocene at about 6,500 to 6,000 yr B.P. These changes in climate may be reflected in the sedimentary record of the study area. It was outside the scope of this study to relate the sediments to specific climate shifts. But the changes indicated in the sediments are consistent with climate shifts documented elsewhere.

The development of extensive carbonate nodules in sediments of Unit IV may have required a few thousand years (Appendix E). Concretions developed while Unit IV sediments were above the water table and were subjected to

seasonal wetting and drying. The position of the Mazama ash in the sediments indicates a shallow-water area following a period of soil formation and erosion. The presence of a shell midden with an indicated age of 6,100 yr B.P. near the same horizon supports the interpretation of sediment accumulation in shallow water at this time. Thus Unit II sediments, above the tephra and midden, are as much as 2,000 years younger than the reported age of the human remains, and represent renewed sediment deposition.

Sometime after the Mazama eruption, changes occurred in the dynamics of the Columbia River system and the river began downcutting and eroding the terrace sediments. Soil-forming processes began again, creating Unit I which is the modern topsoil. One radiocarbon date from a shell midden 2,200 m west of the study area gave an age of 4,100 yr B.P. (sample collected and tested during Phase One). This midden is about 15 to 20 cm below the top of the terrace. It may have accumulated above the water level, implying that the period of emergence and downcutting may have begun.

7.5 Geomorphology

The short duration of Phase Two field activities and the tight focus of this study did not allow the WES team to perform regional reconnaissance of geomorphic features surrounding the study site. This is a step that WES researchers usually complete prior to on-site investigations. In this case, much of our understanding of the regional geomorphology had to come from study of aerial photos and maps spanning almost 70 years.

Interpreting the geomorphology of a site means understanding how the landscape developed and changed with time, why features are there, and how various features are related to each other. In geoarchaeologic studies, it is important to understand what the landscape looked like during prehistoric times to be able to assess the likelihood that people would have lived there. It is also important to identify paleosols and determine the timing and processes of soil formation. Paleosols have the potential to have been ancient living surfaces and to be the location of cultural resources. To understand the Kennewick study site, one needs to know why this was a slackwater area and what landforms were present during late Pleistocene and Holocene time.

Immediately to the east and west of the 350-m study reach, gravel deposits are exposed along the reservoir shoreline. These gravels are bedded and cross-bedded, which means they were transported and deposited by natural geologic processes. Therefore, they are in place and were not hauled in during 20th-century activities. Their position relative to the study reach suggests that they are older deposits than the sediments we studied, and that the slackwater deposits lap onto these gravels. It is probable that these gravels were hard points along the river, consisting of large cobbles and boulders that the river could not move. The slackwater area existed between them.

Gravel to the west of the study area might be associated with an alluvial fan that could interfinger with the layers of the terrace. Waitt (1980) describes pre-flood sidestream alluvial fans elsewhere at the margins of the Pasco Basin and the buried topography they represent. Aerial photos from the 1930's through 1950's indicate a possible drainageway leading down toward the river from the south, near the west end of the study site. This intermittent stream could have spilled out coarse sediments at approximately this location during flash floods. There is no comparable feature indicated at the east end of the site, however, and yet there are similar bedded gravels to the east.

An alternative hypothesis for the origin of the gravels is suggested by close scrutiny of the 1930 aerial photos. In 1930, before there was a reservoir, a large point bar existed along the north shore across the river from the study site, where sediment was being deposited (Figure 20). The river was eroding sediment from the south shore where Columbia Park is now. Even though the river was downcutting along the south shore, several promontories appear on the photo, extending out into the river at fairly regular intervals. The promontories are all roughly parallel, trending in a northeast direction from the shore out into the water. This apparent trend could be a function of the flow direction of the river (west to east), but there are other possible explanations.

These promontories are within the active floodplain. There is one at each end of the study site so these probably are the gravel deposits that defined the extent of the prehistoric slackwater area. It is possible that these roughly parallel gravel promontories are remnants of huge ripples from the receding waters of an early Lake Missoula glacial flood. The modern river can pick up and remove the finer particles, but the boulders and cobbles in these promontories are too large for the river to move. Evidence for this hypothesis includes the geometry of the promontories indicated on the 1930 photo, the presence of the gravels themselves, and the presence of finer grained sediments between them. It is consistent with the geologic history of the area, it would explain the gravel beds at this location, it would put them in place prior to accumulation of the sediments in the study reach, and it would provide a mechanism for creating a quiet-water area. Some combination of flood-gravel ripples and alluvial fan deposits forming the hardpoints would fit the geologic evidence.

The aerial photographs from the 1980's and 1990's show that most of the length of Columbia Park is a series of arcuate indentations between hardpoints. Photos taken during high water show the brown coloring of suspended sediment in the water in the indentations, with blue water at the gravel points. During field reconnaissance, we confirmed that the arcuate indentations are deposits of fine-grained sediments, and the hardpoints are deposits that include cobbles and boulders. Other Columbia Park cultural resource sites have been identified in the fine-grained sedimentary deposits in the indentations. Establishing the geomorphic relationships of these features would provide a better picture and understanding of what the landscape looked like during the past millenia of

human occupation, and delineate additional possible locations for cultural sites of an age comparable to the ancient remains.

7.6 Modern geomorphic processes

The southern shoreline of Lake Wallula at Columbia Park is being eroded by the action of the river. Different erosion mechanisms are active at different places along the study reach. Between station 0+00 and CPP 093, at the east end of the study area, the principal erosive mechanism is mass failure of the bank during periods of high water. When the pool level is high, the fine-grained sediments become water-saturated and heavy. Sudden slope failures can result as flood waters recede. These failures often rotate large blocks (several cubic meters) of sediment into the water in a very short time. Slope failure and rotation of blocks into shallow water happens rapidly, and the sediments are introduced into the water. Blocks that include the plants from the terrace surface remain intact at least temporarily because the thick root mass of terrace plants holds the upper part of the block together. At the Kennewick site, grassy clumps along the shoreline between CPP 044 and CPP 080 are remnants of the terrace surface held together by their root masses, and moved well out from the bankline by slope failure.

Shear failure introduces a large amount of fine-grained sediment into the river. Fine particles are carried away, leaving only the root masses from the surface and the concretions from Unit IV, which are larger particles and not as easily moved. Lag deposits of the concretions have built up along portions of the shoreline, and are especially noticeable between CPP 093 and 044. The shear-failure mechanism would have introduced the ancient remains into the reservoir all at once, rather than their being slowly exposed one component at a time. This is consistent with the fact that separate elements of the remains were still fairly close together in the water. Their grouping in the water also suggests that all of the remains were within one failure block, and therefore were grouped fairly closely in the sediment. If they had been scattered widely in the sediment, it is more likely that different elements would have entered the water over a period of several years, as different blocks failed and entered the river. This probably would have allowed only partial recovery of the remains in any one year.

The concretion-covered elements acted as cobbles in the reservoir and were not moved very far from their point of introduction into the water. Erodible fine sediment was washed away fairly quickly, leaving the skeletal elements within a small zone. It is less likely that the elements were released from the sediment one at a time by wave action. That process would have left the individual elements at the toe of the bank, rather than out in the water, and would have increased the likelihood that someone would have noticed them on land during a slow and gradual process of erosion.

At the west end of the study area, the continuous tephra bed and the thin silica-rich concretionary layer immediately beneath it form an erosion-resistant unit. Sediments below the tephra and silcrete layer are more susceptible to erosion and are being preferentially removed probably by a combination of wave action and mass failure. This undercuts the tephra layer which remains in place as a shelf until it subsequently breaks off in large blocks. Figure 14 shows the erosion-resistant tephra and silcrete layer (Unit III) as a shelf above undercut areas, and the blocks at the toe of the bankline still supporting grasses that were growing on the terrace surface. Boulders of the silcrete with tephra attached form a lag deposit that remains even after the topsoil is washed away, and are close below the bankline rather than out in the reservoir, as is consistent with their mode of origin.

Analysis of aerial photographs taken from 1953 through 1996 revealed the extent of bankline erosion. The pool behind McNary Dam was filled in 1953, creating Lake Wallula. Photos were available from 1930, 1953, 1955, 1962, 1983, 1987, 1991, and 1996. Matched features from each photograph were rectified to the USGS 7.5-minute quadrangle map from 1992 for positional accuracy, and the photos were overlain using geographic information system (GIS) software. In the time since the reservoir was filled, the bankline has receded by as much as 15 m. Some of this erosion can be attributed to periodic flooding, when the bank becomes saturated and experiences mass failure. Floods in 1996 probably caused the sediment block enclosing the remains to drop into the reservoir, so the sediments exposed in the present bankline at the ancient remains site have been exposed for less than 2 years. Wave action and surface runoff continue between floods and cause multi-level terraces to form, such as those pictured in Figures 4 and 7. The exposed sediments become terraced because units with abundant concretions or mineralized layers are more resistant to waves and surface wash. Bedding planes swept clean of fine sediments were observed in shallow water during on-site visits in October and November 1997, indicating that the Columbia River continues downcutting along the south bank of the reservoir.

7.7 Geoarchaeologic interpretation

When the sediments accumulated, the study area was a slackwater adjacent to the Columbia River. Adjacent gravel banks may have been in place for hundreds to a few thousand years. The area may have been thickly overgrown with plants at some times and at other times had no standing water, but still was rich in plant and animal life. The river and wetlands would have provided excellent food and other resources necessary to sustain human life. South of the slackwater area was a higher bluff of older Missoula flood gravels (Highway 240 was constructed on these gravels). This bluff could have provided a living surface above the threat of seasonal floods and a strategic high point overlooking the river and lands to the north. The evidence of the shell middens and various

flakes and fire-cracked rocks indicates that the area was occupied by people repeatedly or continuously over several millenia.

Geologic data collected during Phase Two do not indicate a burial mechanism for the ancient remains. Some of the best examples of intact skeletal remains of large vertebrates are associated with coarse-grained sediments deposited during flash floods, such as the famous conglomerate fossil beds of Dinosaur National Monument (Untermann and Untermann 1969). The energy required to move a person would be less than the energy that carried dinosaurs millions of years earlier. With the exception of Unit IV, however, there are no sediments that can be associated with flash floods in the sequence studied at the Kennewick site. All the sediments are more mature, that is, well sorted, from being carried and deposited gradually. Thick emergent vegetation associated with slow continuous deposition in the slackwater area and periodic dry times might have physically deterred introduction of a large floating object. However, if the individual was floating at a time of extremely high water, this same vegetation could have held him in place if he washed into the slackwater area so he could be buried subsequently by natural sedimentation.

Data from grain-size analyses available at present neither support nor refute the hypothesis of accidental incorporation of the human remains into sediments. The units above the concretion-rich Unit IV are younger than the Mount Mazama event. They are therefore at least 2,000 years younger than the remains, and could not have been present to contribute to the soil used in an intentional burial. Because of the period of erosion indicated by remnants of a buried soil horizon, the characteristics and thickness of sediments that may have overlain Unit IV before that erosion are unknown. The size and sorting of sediments at different depths within Unit IV may be so similar that it may not be possible to differentiate among these different sediment intervals with statistical significance. The question of association of the remains with one sedimentary interval is still open.

On the other hand, no indicators of intentional burial were detected during Phase Two field studies, either. The limited geophysical survey revealed no obvious anomalies to indicate gravesites. Due to continued erosion of the bank line, there is no way to establish the original positional relationship between the remains and the sediments by studying only the sediments in the bank. The data available can be interpreted in different ways to support multiple hypotheses about how this individual came to be buried in Kennewick. Careful study of the sediments still associated with the remains is the only potential source of geologic information that might answer some of the questions about positioning or burial.

8 Conclusions and recommendations

8.1 Conclusions about geologic setting and age of the Kennewick site

The landform associated with the ancient remains is between 16,000 and 4,000 years old. The 9,000-yr age reported for the remains fits consistently within the geologic events indicated by site geology. That is, finding 9,000-yr-old remains here is consistent with the sedimentary environments and landscape features of the site. Various parts of the geologic picture fit neatly together in the same sequence with temperature and climate changes, periods of accretion, erosion, and soil formation, and volcanic events known for this region from independent evidence. Relative ages of features of the site stack up in chronological order. The sediments began accumulating more than 15,000 yr B.P. during catastrophic glacial flooding. A slackwater area adjacent to the Columbia River underwent periods of deposition, subaerial exposure, and pedogenesis, creating a composite sediment column including rhythmite and at least one paleosol. The remains were buried in sediments which experienced both wet and dry times. That is, the individual could have come to rest here when the area was either under water or emergent.

Mount Mazama experienced its great caldera-forming eruption 6,700 years ago, sending distinctive volcanic ash over the region. The ash was stabilized and thickened in low wet areas, following a dry period when soil formed and was subsequently eroded away. The sequencing of the Mount Mazama eruption and paleosol formation could not be established beyond question in a 2-dimensional study of 3-dimensional landforms. The volcanic event occurred after a major episode of soil formation and erosion and after the remains came to rest here. As geologic events, the soil formation and tephra accumulation establish the age of the landform.

A shell midden accumulated above the level of the Mazama ash, probably near the bank of the river at a time when the area was wet again. The midden is stratigraphically higher than the volcanic ash layer, so the sequence is consistent with the reported ages of shells, 6,500 and 6,100 yr B.P. Subsequent deposition ceased and the river began eroding the terrace. The time sequence established

by these events is in the same order as the layers themselves. That is, modern disturbance to the area has not destroyed the stratigraphic sequencing of events. The stratigraphic features can be used with scientific confidence as relative age indicators of features within the strata.

Finding the remains in a group in the water was consistent with modern geomorphic processes. The erosion that is occurring where the remains were found is largely from slope failure following times of flood and causing large blocks of the reservoir bank to slump into the water very rapidly. The remains did not move a great distance from their point of entry into the water, because they acted like cobbles in the riverbed. They were too large to be transported a great distance in the lower-energy sediment-transport system of the reservoir. The fine-grained sediments with them, however, were quickly eroded away, leaving only the remains and the sediment attached to them by natural mineral cement.

8.2 Conclusions about site archaeology

Phase One and Two site investigations were largely geologic studies. Only minimal archaeologic interpretation can be justified by this research. The study revealed no evidence for any specific cultural affiliation for the ancient remains or for any other cultural materials. The geologic evidence supports associating the remains with the concretion-rich layer (Unit IV) between CPP 125 and CPP 054, but no archaeologic evidence to support or refute this association came to light. Cultural items were located at the study site, and at one location they apparently came from a stratigraphic position lower than the remains. It is significant that artifacts and ecofacts with human association were found possibly in place, considering the small amount of sediment moved and screened. The study revealed no direct evidence for either intentional burial of the remains or burial by natural processes, so the questions about cultural affiliation and method of burial are still open.

The area was used by people either repeatedly or continuously for thousands of years. This is consistent with the known occurrences of other cultural sites along the Columbia River spanning a long range of time. The remains themselves, the shell midden at 6,100 yr B.P. and the midden 2,200 m upriver at about 4,000 yr B.P. are adequate evidence of long-term human use of this rich riverside environment.

8.3 Recommendations

Phase Two study established that the geologic age of the site is consistent with the reported 9,000-yr age of the remains. The remains apparently eroded out of the concretion-rich layer, but the interpretation is weak without data from the sediments still stored with the remains. Study of these sediments should include chemical and mineral composition, size and shape of concretions, ratio of carbonate to silicate cement in concretions, color, particle-size parameters, and AMS age dating of the associated sediments and comparable data from likely positions in the bank sediments. Data from several properties of the sediments, analyzed with appropriate statistical rigor, will relate the remains to a specific stratigraphic horizon and geologic age, and may provide data to address the question of how the remains came to rest in the sediments of a river terrace.

The presence of several sources and ages of calcium carbonate in the sediments may lead to erroneous age dates. Ages of carbon in shells, the soils, and the remains themselves should be verified by the best available techniques, and interpreted with an awareness of geochemical processes that could affect age dating. However, the abundance of calcium carbonate and concretions may have contributed to the remarkable preservation of the human remains. Pedogenic calcium carbonate and slightly alkaline conditions in soil above the pool level of the reservoir are geochemical protectants to some natural substances. Any additional study of the remains should include a summary of published literature about geochemical conditions that contribute to bone preservation in fine-grained alkaline sediments.

A study limited to the 2-dimensional bankline did not provide enough information to interpret all features of the 3-dimensional landform and stratigraphic sequence. Because of public and scientific interest in the ancient remains, more complete characterization of site geology is warranted so that the site can be understood and discussed in a regional holistic setting. Additional site study should be planned to have minimal impact on cultural and natural resources of the area.

A geophysical survey of the entire study site is the next logical phase of the research. Geophysical techniques should make it possible to determine if there are other potential burial sites on the terrace, and to delineate the interfaces between the fine-grained sediments and the enclosing gravel deposits.

Full characterization of the geologic setting and landform at the Kennewick site probably will require invasive study. Previous WES studies of the geomorphology and geoarchaeology of sites around the world have involved trenching (Albertson and Dunbar 1993), pitting, or coring (Stanley and Warne 1993; Britsch and Dunbar 1990) to obtain the information needed, but seldom require all three approaches.

The combination of vibracore sampling and geophysical tools was used during the December field investigations at the human remains site to reveal and sample the sediments underlying the site. The vibracore sampling device penetrated and sampled to a maximum depth of approximately 2 m below lake level (approximately 4.5 m below the top-of-bank). The GPR investigated to a depth of approximately 2 m below the top-of-bank. The sediment column penetrated by the vibracore and described in bank profiles was essentially monotonous strata consisting of silts to fine sands. The human remains site is characterized as fine-grained slackwater deposits lying between graveliferous deposits to the east (downstream) and west. Neither geophysical techniques nor vibracoring defined the base or 3-dimensional geometry of the fine-grained deposits observed at the site.

A delineation of the base of the fine-grained unit and the geometry of its contact with the underlying older units is essential to a full understanding of the geology, sedimentation history, and relationship of the site to the general setting of the Pasco Basin. Delineation of the base would help place the fine-grained geologic unit in its proper perspective with regard to the other geologic units in the Pasco Basin, which include older alluvial units, coarse-grained cataclysmic flood deposits, fine-grained sands and rhythmites also associated with the cataclysmic flood events, and the well-defined and amply described and dated tephra marker beds in the area.

There are three geophysical exploration techniques with the potential to detect and delineate the probable base of the fine-grained unit. These are seismic refraction, multi-frequency electromagnetic (EM) surveying, and resistivity sounding. Seismic refraction determines the depth to and seismic velocity of successively denser layers of soil or rock. An energy source at the ground surface imparts a seismic wave into the subsurface that is refracted (bent) at the interfaces between layers of differing density and/or seismic velocity. Geophones arrayed in a line or lines away from the source at the ground surface receive the refracted waves (signals) from the subsurface. Plots of arrival times at the phones versus distance from source to phone permit recognition of the layers and calculation of their respective depths and seismic velocities. An estimation of material type (saturated or dry, soil or rock) representing the layers can be made from the seismic velocities. The geometry (orientation or dip), of the surface of each layer can also be derived from the seismic data.

Multi-frequency EM measures differences in electrical conductivity of the subsurface materials. Conductivity is affected by differences in soil porosity, water content, soil chemistry, soil type, and by contained non-soil artifacts. The EM equipment induces an EM field into the subsurface as the tool is carried near the ground along prearranged grid lines. A receiver in the same unit measures the strength of the secondary field that is generated within the subsurface. Contouring of the detected values of conductivity permits mapping of the changes in conductivity within the grid. The apparent depth to objects or layers

of varying conductivity can also be calculated. An EM survey is usually run in tandem with the seismic refraction survey to augment interpretations of anomalies in the subsurface.

Resistivity surveys induce an electrical current in the ground through copper electrodes driven a short distance into the soil. Other electrodes measure the variations in the potential of the electrical field. Variations in the resistivity, an intrinsic property of earth materials, produce variations in the measured electrical potential, thereby revealing something about the composition, extent, and physical properties of the subsurface materials. Resistivity soundings expand the distance between the current electrodes gradually, allowing consecutively deeper sections of the earth to be penetrated by the current. Interpretation of the resistivity data reveals the depth to layers of differing resistivity and an estimate of layer composition.

The seismic refraction method uses either blows from a heavy hammer to a steel plate on the ground surface or light explosive charges embedded 0.25 to 1 m in the ground to impart the seismic wave. The method is relatively non-destructive and non-intrusive. At the human remains site, ample space is available on the top bank between the bank's edge and Columbia Park Road to run several lines of refraction survey. The depth of investigation in a seismic refraction survey is roughly one-third the length of survey line (distance from the source to the most remote geophone). The depth to which the seismic energy can penetrate is limited by the acoustic properties of the subsurface materials. Soft sediments that absorb energy attenuate the seismic wave and decrease the depth achievable. Denser, "harder" soils and rock, and saturated materials, propagate the wave with less attenuation and permit deeper penetration.

Conditions at the human remains site should allow depths of perhaps 15 to 20 m to be investigated with the refraction seismic and EM methods. Other EM survey methods also have the potential for detecting and locating buried anomalies for archaeological investigation, such as grave sites, refuse dumps, large artifacts, and other localizations of disturbed soil or different material, but must be conducted on a much tighter grid spacing.

Complementary seismic refraction, multi-frequency EM, and seismic refraction surveys of accessible portions of the upper bank area in the 350-m study reach could be conducted with companion vibracore sampling. The entire area of interest could be surveyed and sampled in 1 week, weather permitting. An archaeological search using a dense EM grid would require additional time.

Coring combined with geophysical techniques may be the best way to minimize site disturbance while still gaining a 3-dimensional definition of the landform together with samples for further analysis and physical confirmation of geophysical data.

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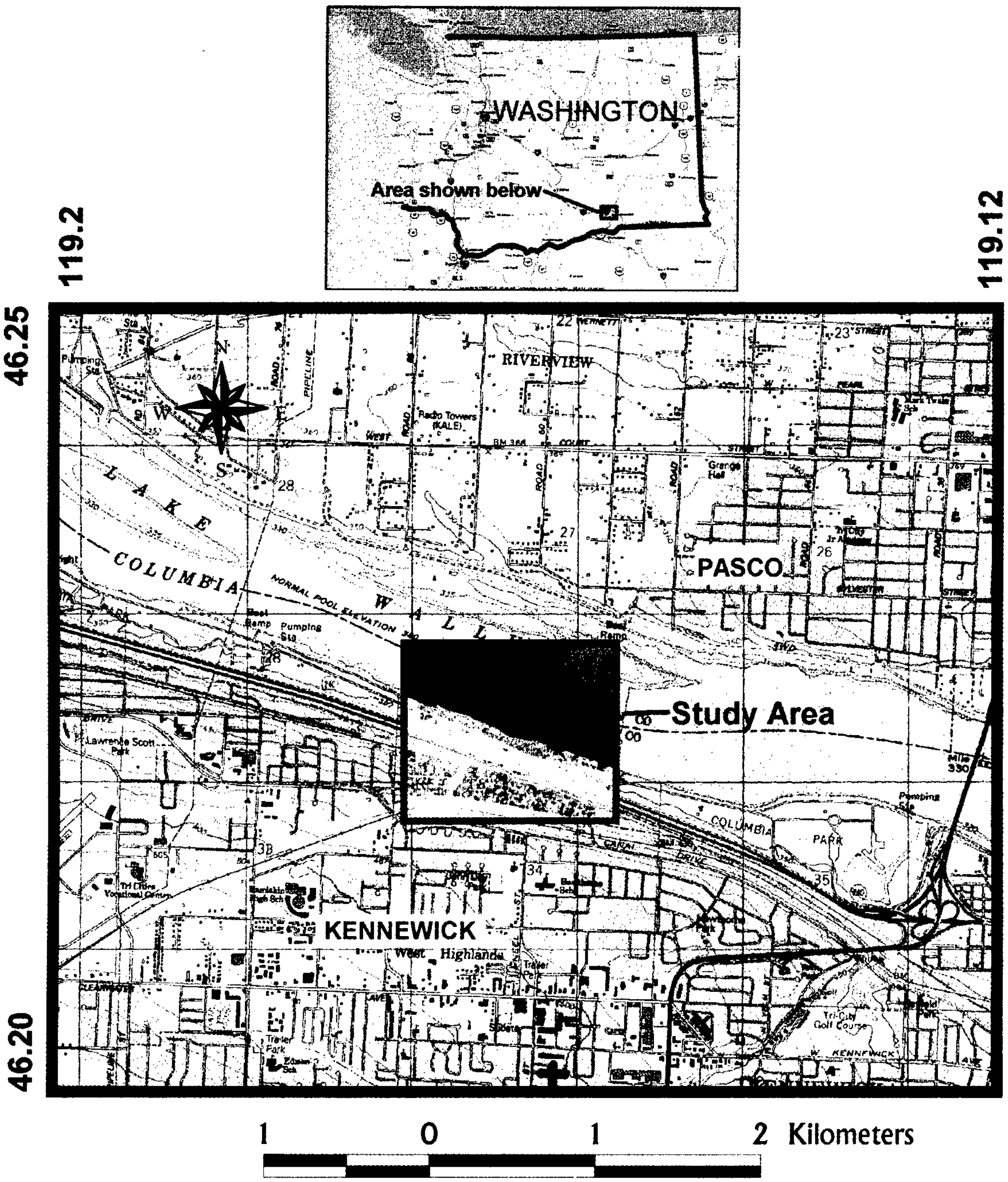
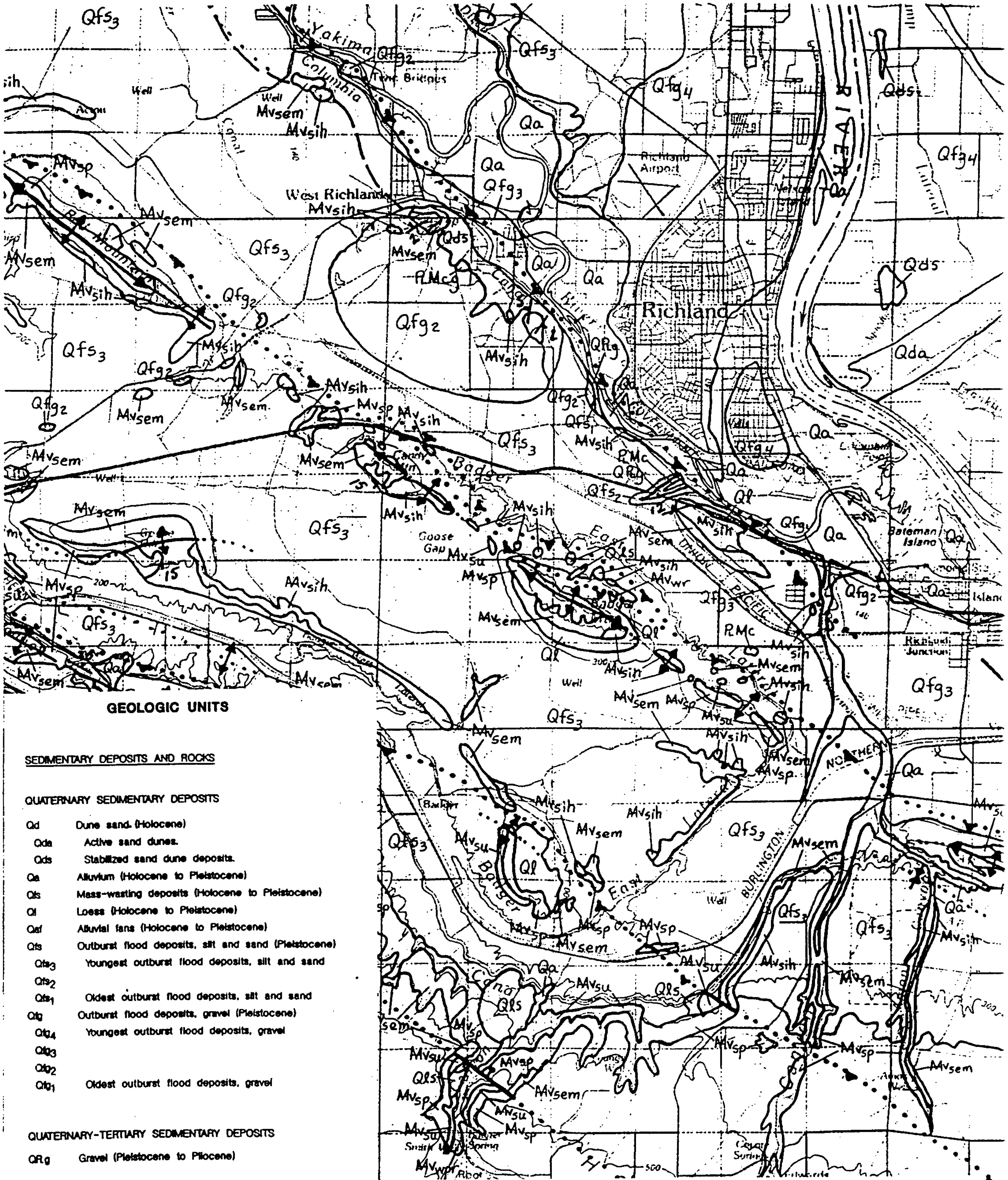


Figure 1. Portion of Kennewick 7-1/2 min topographic map with photo inset of study area.



GEOLOGIC UNITS

SEDIMENTARY DEPOSITS AND ROCKS

QUATERNARY SEDIMENTARY DEPOSITS

Qd	Dune sand. (Holocene)
Qda	Active sand dunes.
Qds	Stabilized sand dune deposits.
Qa	Alluvium (Holocene to Pleistocene)
Qls	Mass-wasting deposits (Holocene to Pleistocene)
Ql	Loess (Holocene to Pleistocene)
Qaf	Alluvial fans (Holocene to Pleistocene)
Qfs	Outburst flood deposits, silt and sand (Pleistocene)
Qfs_3	Youngest outburst flood deposits, silt and sand
Qfs_2	
Qfs_1	Oldest outburst flood deposits, silt and sand
Qfg	Outburst flood deposits, gravel (Pleistocene)
Qfg_4	Youngest outburst flood deposits, gravel
Qfg_3	
Qfg_2	
Qfg_1	Oldest outburst flood deposits, gravel

QUATERNARY-TERTIARY SEDIMENTARY DEPOSITS

QRg	Gravel (Pleistocene to Pliocene)

TERTIARY SEDIMENTARY DEPOSITS

RMc	Continental sand, silt, and clay beds (Pliocene to Miocene). Ringold Formation.
RMcg	Continental conglomerate (Pliocene to Miocene). Ringold Formation.
Mc	Continental sedimentary deposits (upper and middle Miocene). Includes Ellensburg Formation.

SCALE 1:100,000

1 0 1 2 3 4 5 6 7 8 9 10

KILOMETERS

1 0 1 2 3 4 5

MILES

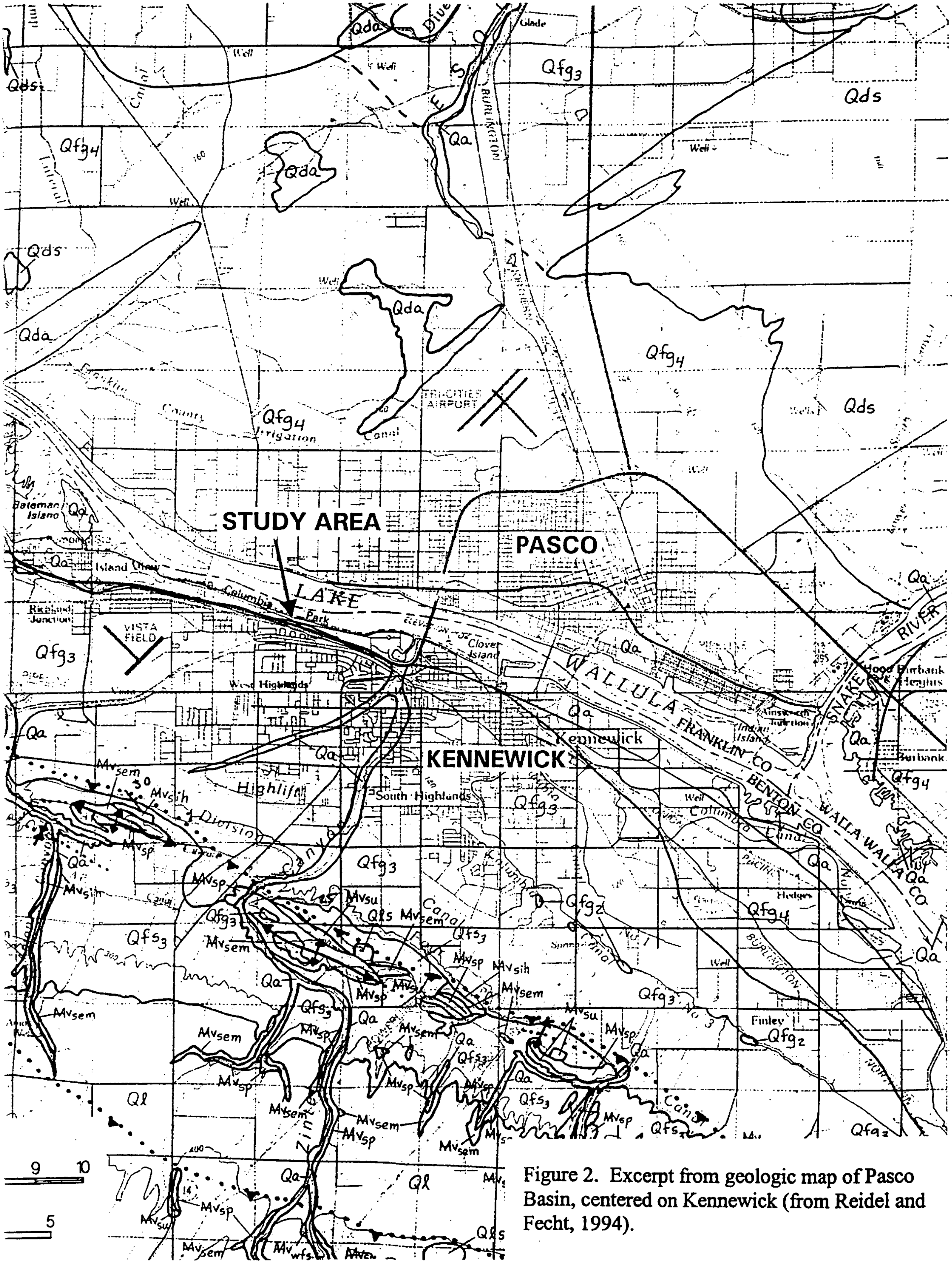


Figure 2. Excerpt from geologic map of Pasco Basin, centered on Kennewick (from Reidel and Fecht, 1994).

Figure 3. On-site consultation about profile locations with representatives of all study teams (from left: Drs. Huckleberry, Stafford, Chatters, Wakeley, Jaehnig, and Briuer).

Figure 4. CPP 268, a stepped profile, with Wanapum Band observer.

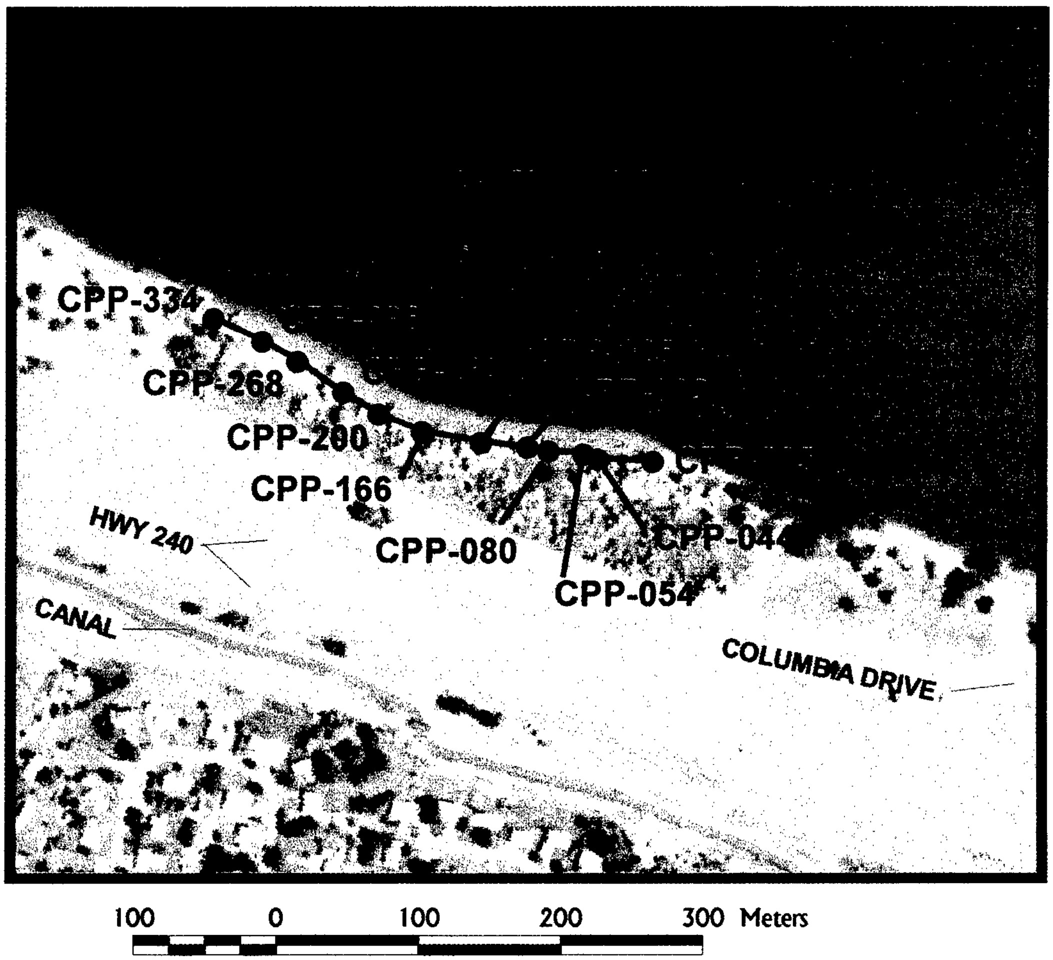


Figure 5. Aerial photo of study area (inset of Figure 1) showing locations of profiles and cross section BB'.

Figure 6. CPP 233, single-face profile exposing 176 cm of bank sediment.

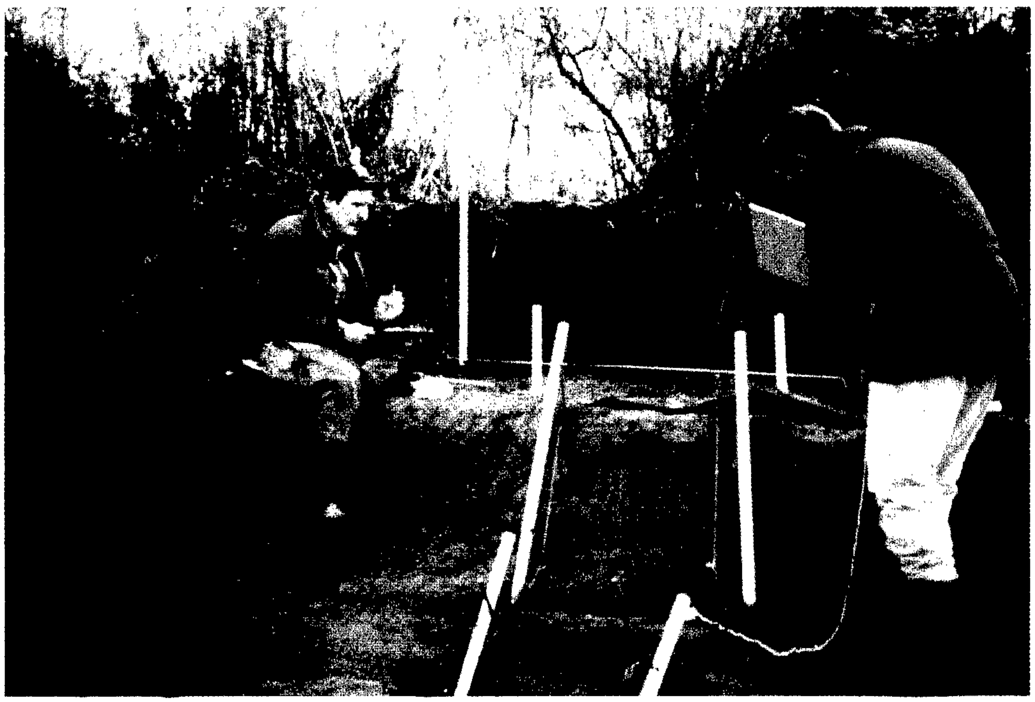


Figure 7. Profile CPP 054, stepped back at three levels for minimum site disturbance (core CPC 059.5 located on step-back terrace through center of photo).

Figure 8. Screening sediment at CPP 334.

Figure 9. Detail of sediment screening (gloves worn only in coldest weather).

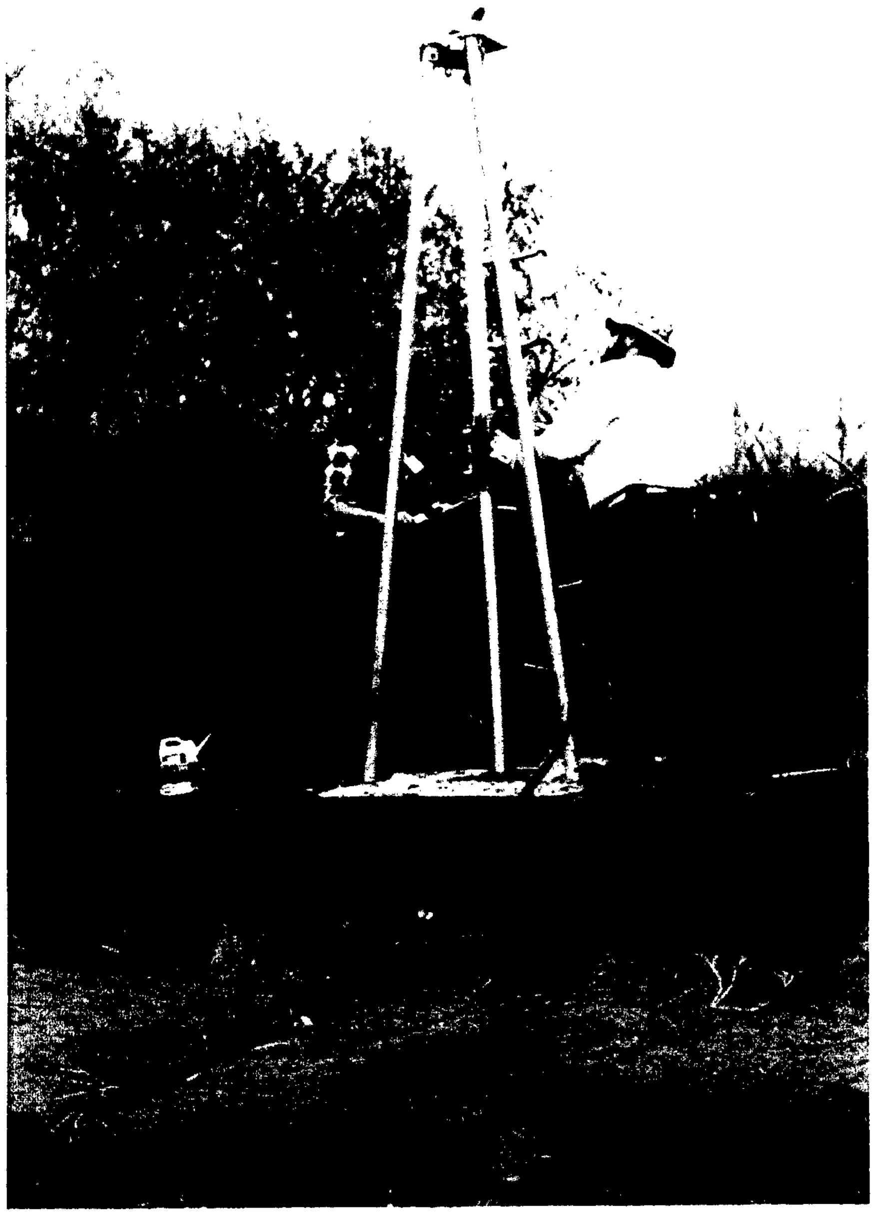


Figure 10. Vibracore device at CPC 059.5 operated by WES and CENWW researchers.

Figure 11. Vibracoring with reservoir pool level lowered, near screening and profile sites.

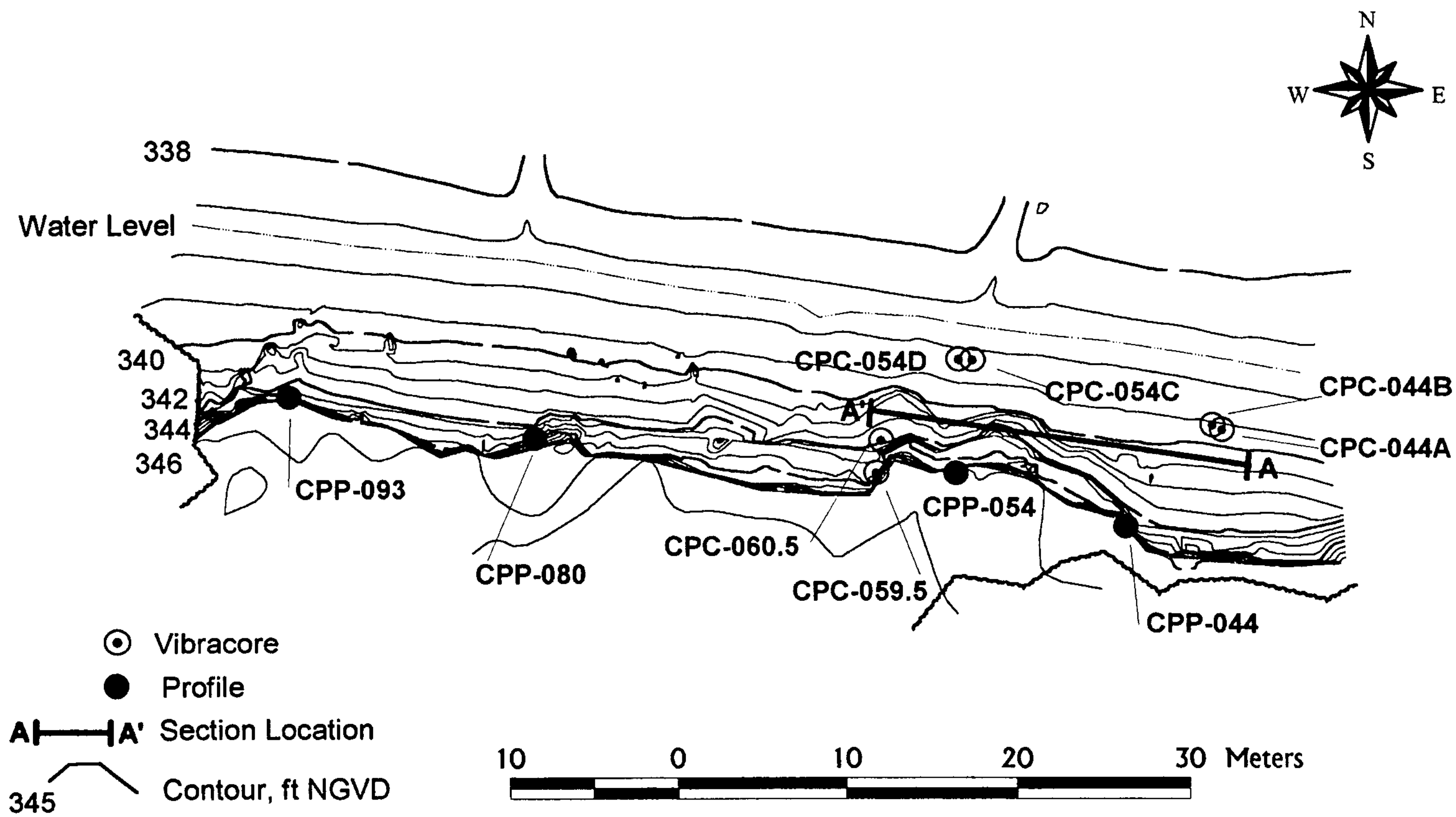
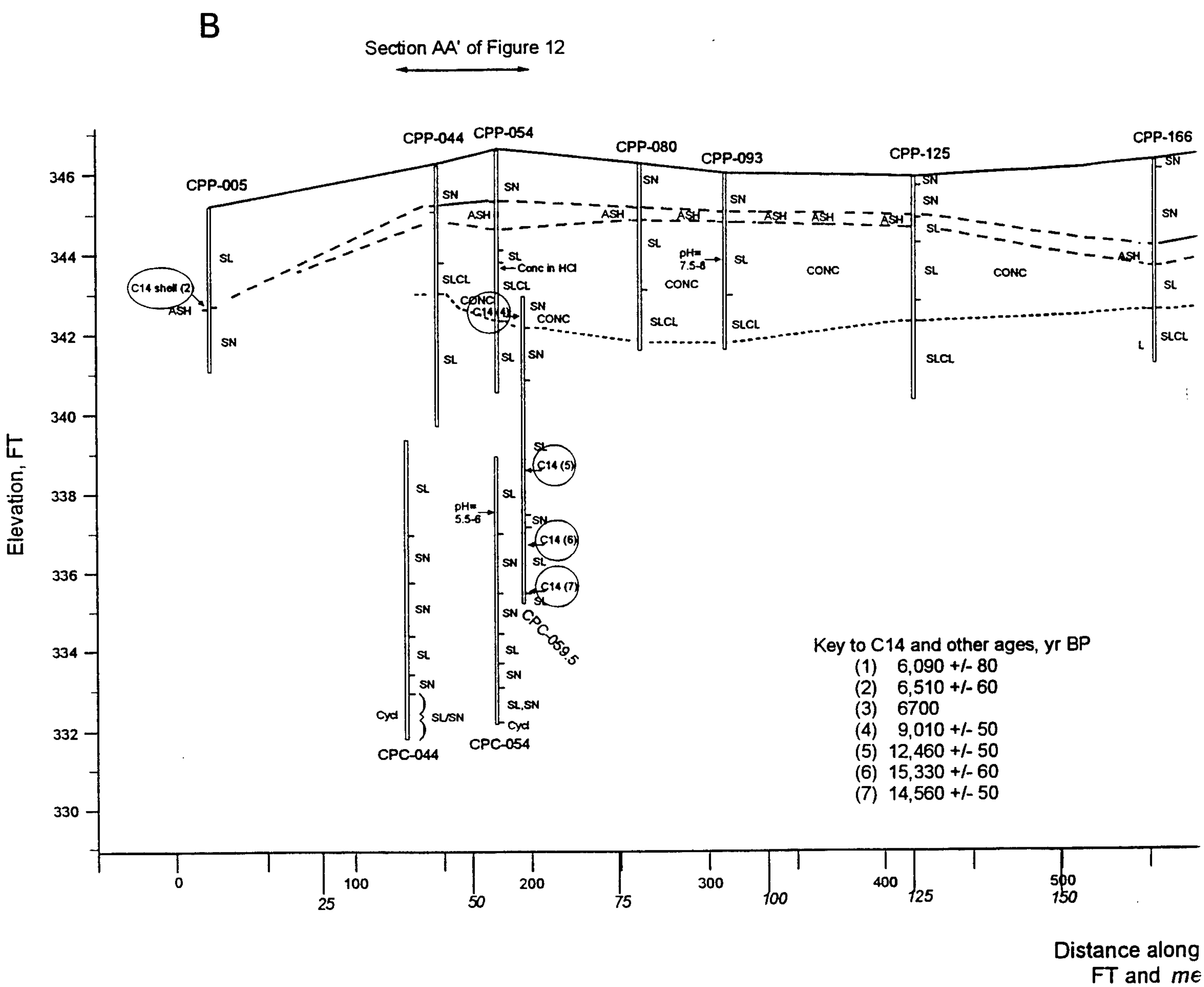


Figure 12. Topographic contour map of area from CPP 044 to 093, indicating profile and core locations. Cross section AA' also indicated.



LEGEND

SL	Predominantly silt or silty loam
SLCL	Predominantly silty clay or silty clay loam
SN	Predominantly sand or sandy loam
CONC	Concretions present (- - - - - - - - is base of CONC zone)
Cycl	Cyclic graded bedding, silt to sand
L	Lithic artifacts
→ Conc in HCl	Concretion from this position dissolved in HCl
→ pH=??	pH of soil at this position tested
→ C14	Sample from this position Carbon-14 dated
C14 shell	Shell from this position Carbon-14 dated

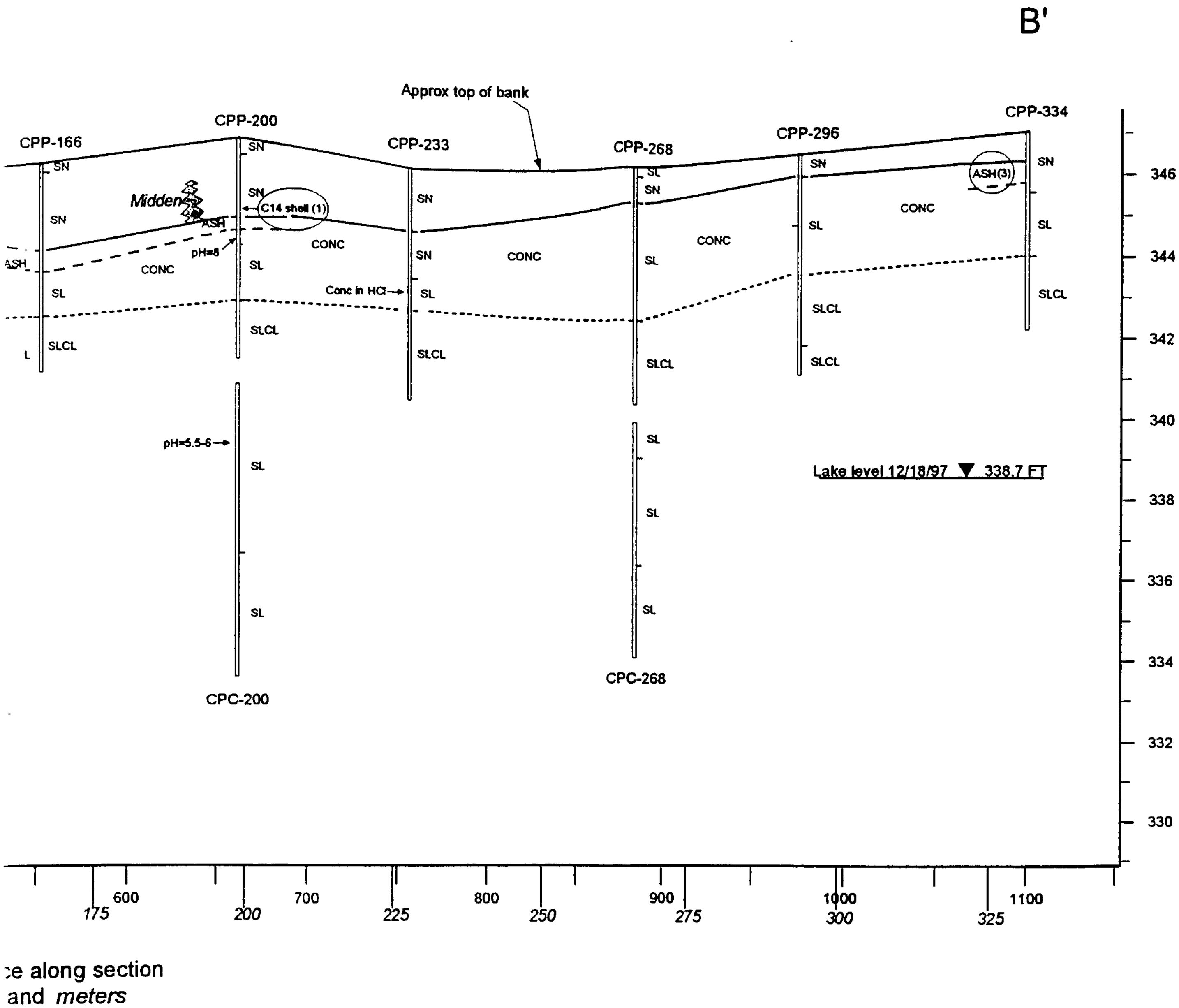


Figure 13.
Correlation of cores and profiles along line B-B' (indicated in Figure 5), also showing locations of samples taken for various tests.

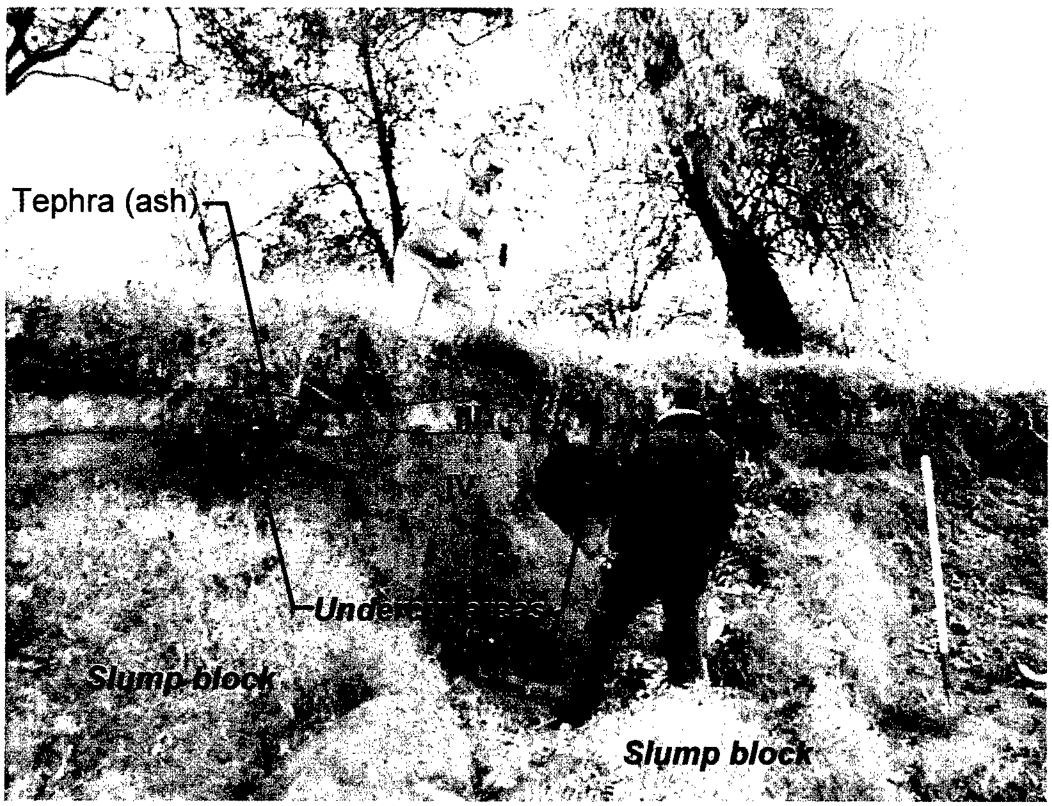


Figure 14. Continuous layer of tephra (Unit III) at the west end of the study site.

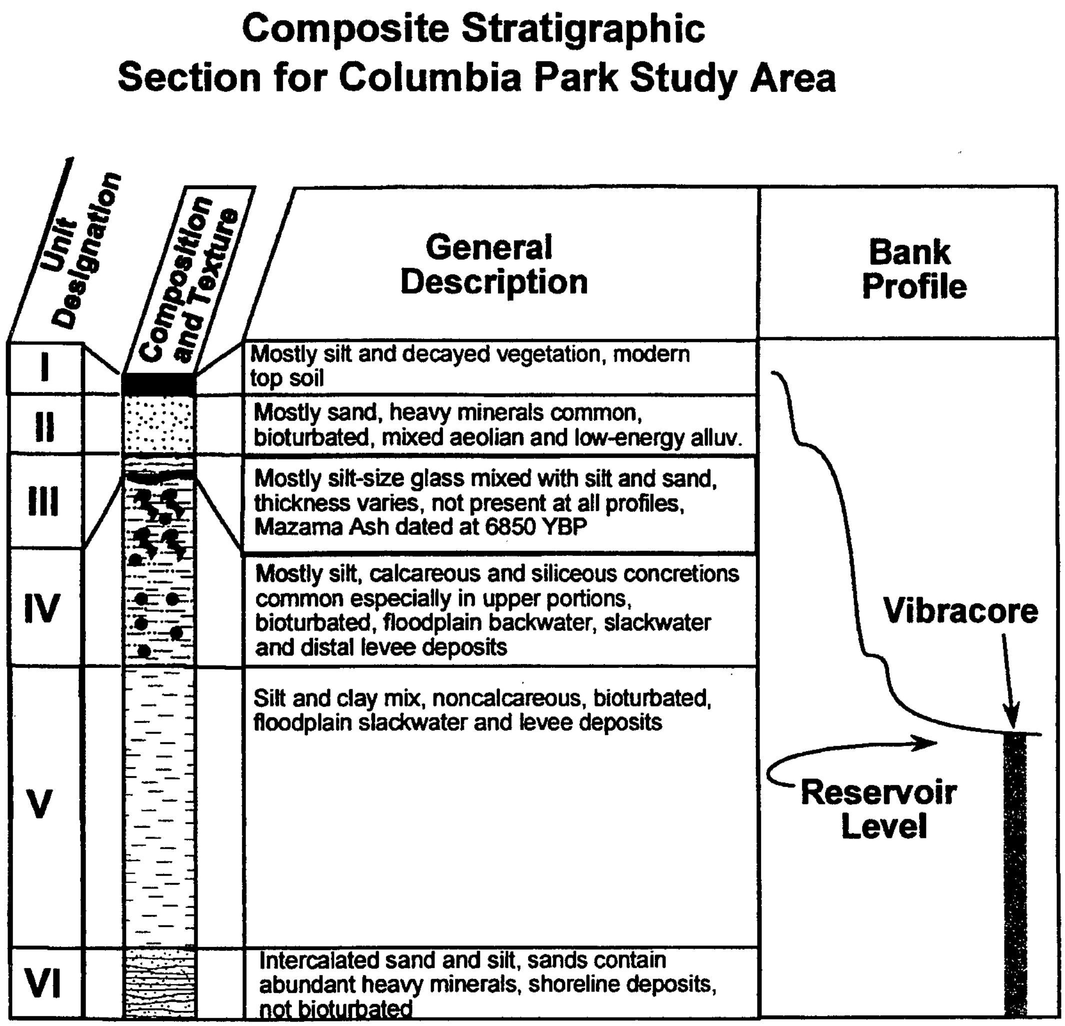
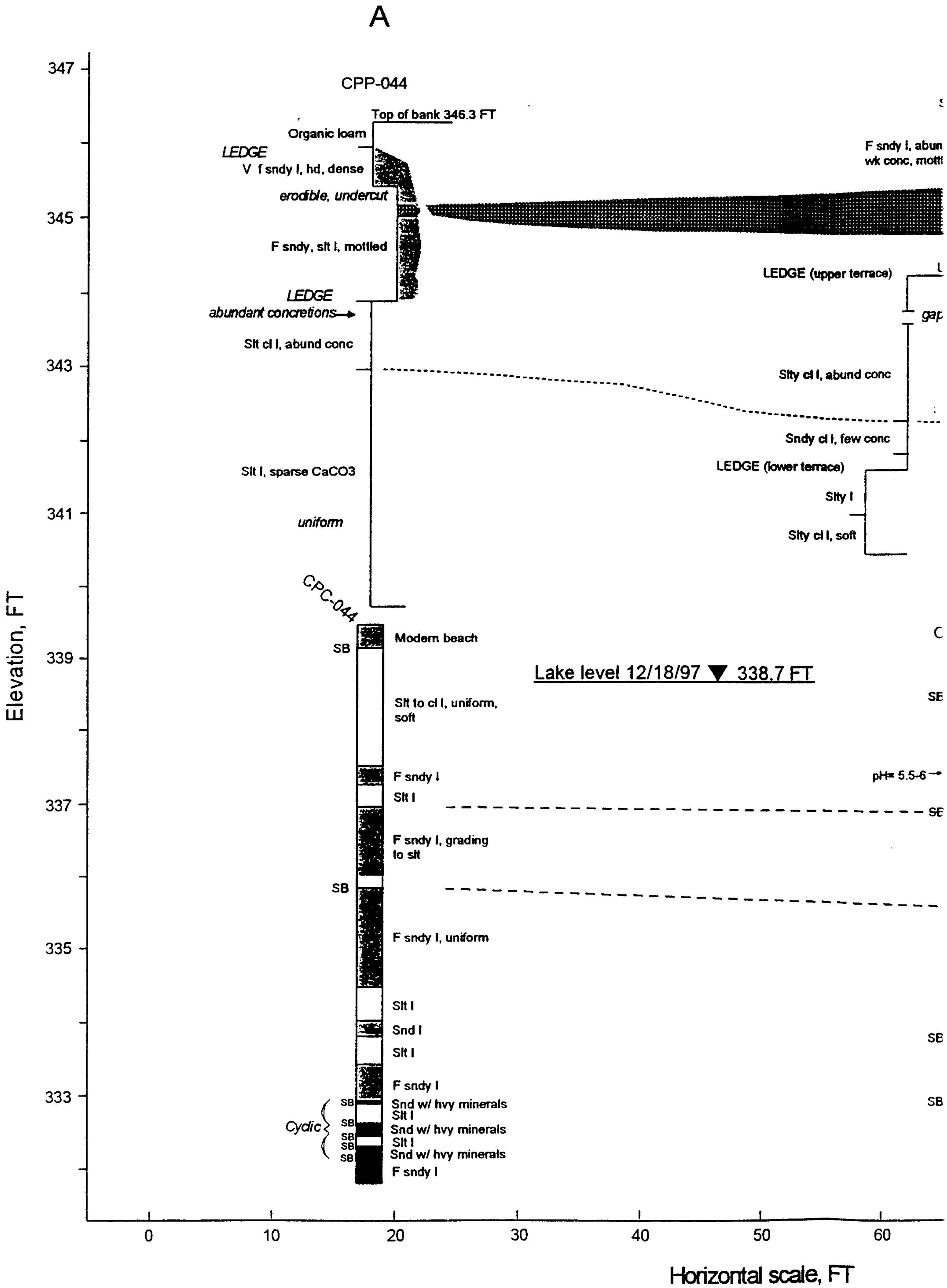


Figure 15. Composite stratigraphic section for Columbia Park study area.

Figure 16. Looking east from CPP 080 to CPP 054 along bankline, units I through IV exposed.



A
CPP-044
Top of bank 346.3 FT
Organic loam
LEDGE
V f sndy l, hd, dense
erodible, undercut
F sndy, slt l, mottled
LEDGE
abundant concretions
Slt cl l, abund conc
Slt l, sparse CaCO3
uniform
F sndy l, abun
wk conc, mottl
LEDGE (upper terrace)
gap
Slty cl l, abund conc
Sndy cl l, few conc
LEDGE (lower terrace)
Slty l
Slty cl l, soft
CPC-044
Modern beach
SB
Lake level 12/18/97 ▼ 338.7 FT
Slt to cl l, uniform, soft
F sndy l
Slt l
pH= 5.5-6
F sndy l, grading to slt
F sndy l, uniform
Slt l
Snd l
Slt l
F sndy l
Snd w/ hvy minerals
Slt l
Snd w/ hvy minerals
Slt l
Snd w/ hvy minerals
F sndy l
Cyclic
Elevation, FT
347
345
343
341
339
337
335
333
0
10
20
30
40
50
60
Horizontal scale, FT

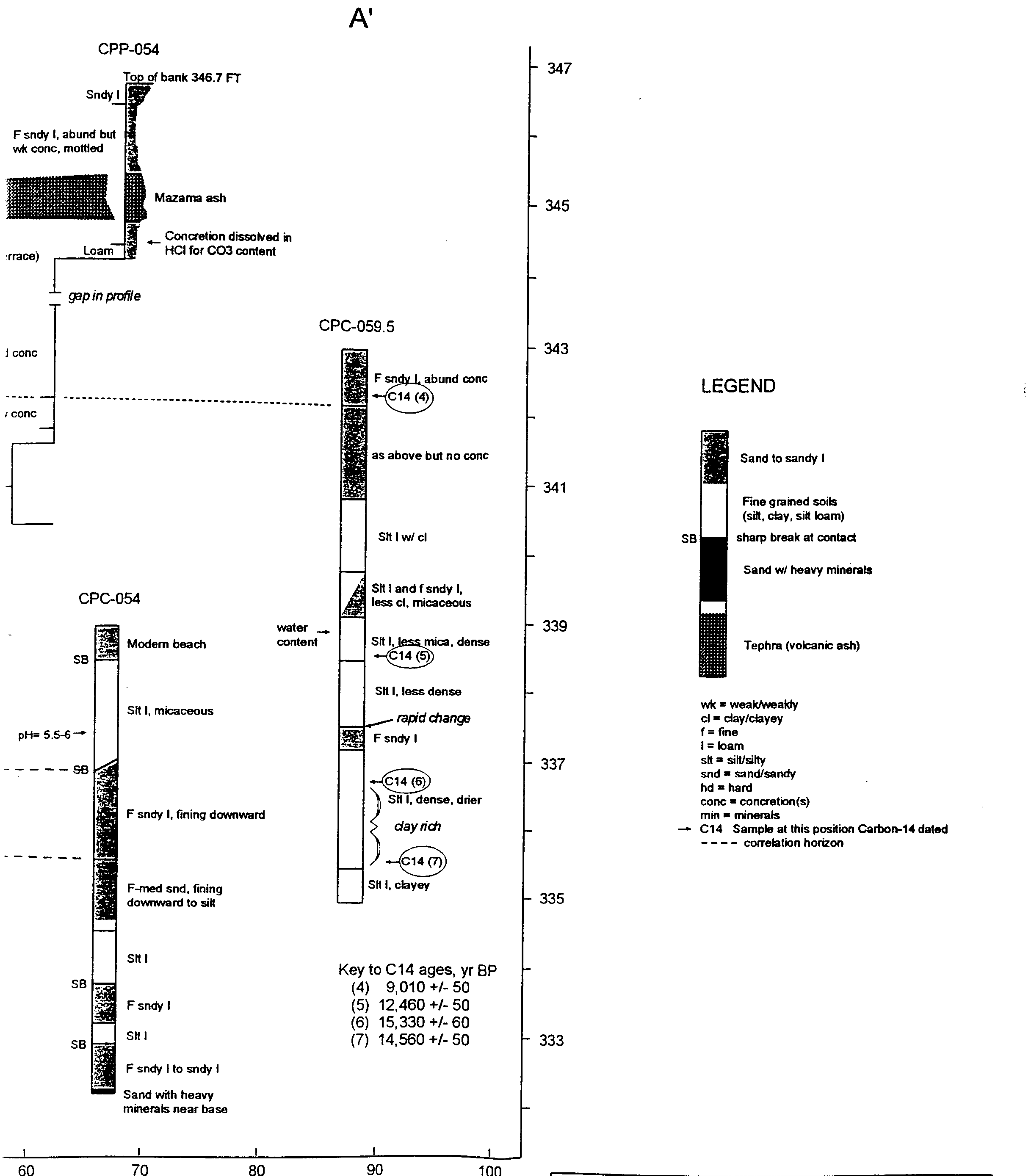


Figure 17.
Correlation among profiles and cores in the immediate vicinity of the discovery site (Section A-A' from Figure 12).

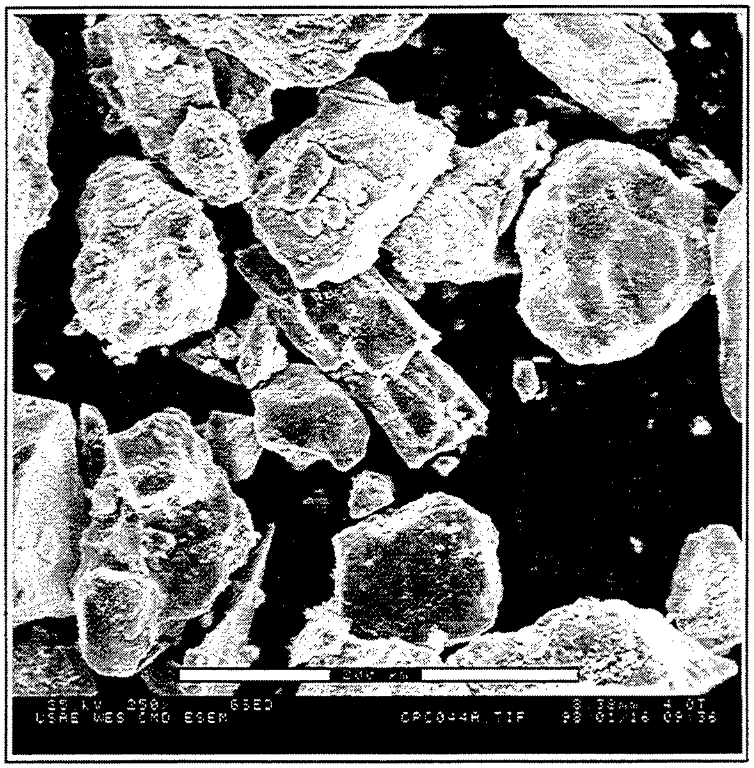


Figure 18a. SEM image of Kennewick site tephra.

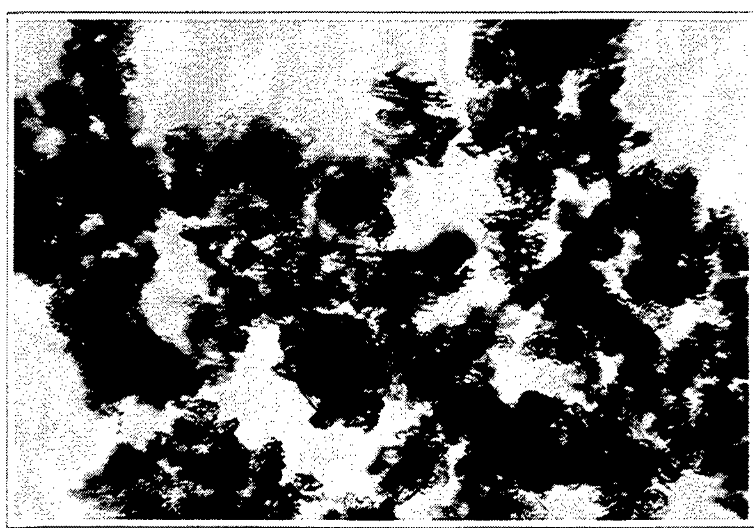


Figure 18b. Photomicrograph of tephra in transmitted polarized light.

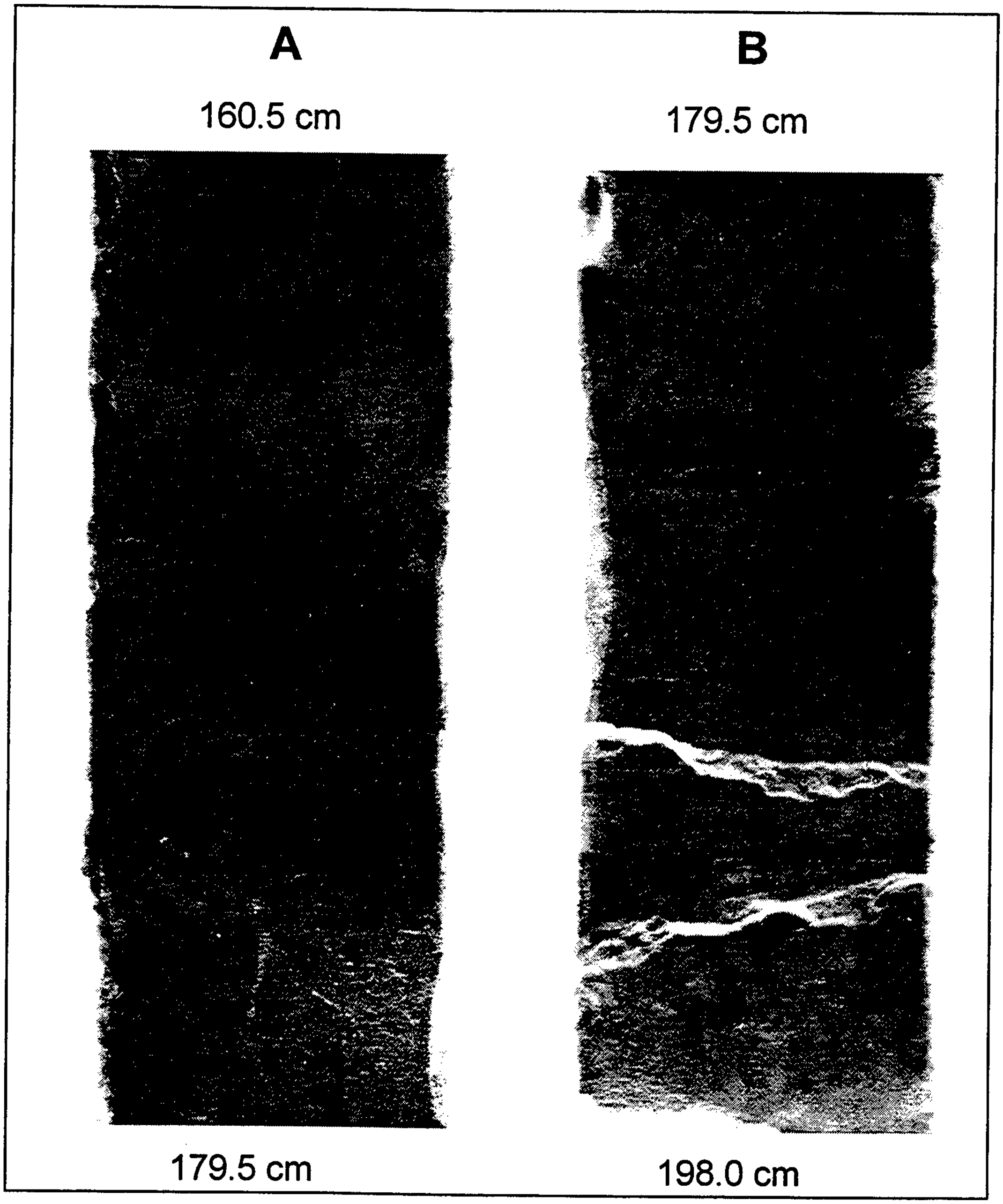


Figure 19. Print from radiograph of Vibracore sample from CPC-044, 160.5 to 198.0 cm depth. (A) shows little stratigraphic structure due to bioturbation, (B) shows wavy and horizontal laminations.

Appendix A

Scope of Work and
List of Participants and Observers,
Phase Two Study,
Kennewick Site

CEWES-GG 8 December 1997

SCOPE OF WORK

PROJECT TITLE: Geological, Geoarcheological, and Archeological Investigations of Cultural Resource Discovery Site, Kennewick, WA

Objectives and Approach

Objective: Determine the stratigraphy, age, chronology, environments of deposition, and geomorphic processes indicated by features of the sediments from which the ancient remains may have eroded, and by adjacent exposed geologic features along the reservoir shoreline.

Approach: Define the linear exposed boundaries of the sedimentary units in the investigation area, in particular those that may have enclosed the human remains. Identify and sample individual stratigraphic units and determine their vertical and spatial relationships and depositional processes. Identify and sample any geologic or non-cultural materials, from the exposure and from adjacent areas that can be sampled by soil probe, auger, or soil cores, and that may indicate age or chronology of the site. Determine if cultural resources are exposed or indicated. Develop a conceptual model of geomorphic and geologic processes that were active at this site when the remains were incorporated into this stratigraphic unit, and those that have been active since that time. Scope is limited to the features that are likely to be covered by or disturbed during bank stabilization (Phase 2 investigations). The investigations will provide information to determine if further invasive studies are required, so that disturbance at the site is kept to the mission-essential minimum.

This scope of work has been coordinated with the Interagency Task Group including representatives from the Department of Interior, the Department of Justice, the Office of the Chief of Engineers, and with both ARPA permit groups.

Specific Task Definition:

Description and assessment of historically recorded human and natural events in and around the site and regional geology. Open exchange of information between and among Government representatives and the ARPA permit participants is encouraged.

Evaluate historic charts, maps, and photographs to determine landform and land use prior to reservoir filling. Identify likely historic human impacts on the site (such as infilling wetland areas, intensive irrigation and farming, etc.) or

other recent human activity that may have changed the distribution or geochemical characteristics of earth materials at the site. Assess published geological literature to identify the general geologic setting of this region, and the geological processes such as ice-dam floods and volcanic eruptions that shaped this region.

Summary of Condition, Distribution, Location of Remains Upon Discovery and Recovery. Describe the distribution of the human remains, artifacts, and other associated material when they were discovered, using written notes and reports and interviews with those present at the time. Summarize how remains and artifacts were collected, when, and from what locations as precisely as possible. Determine whether any soil that might be associated with the original geomorphic position of the remains might have been with them when they were collected or still might be recoverable from the remains.

Stratigraphic continuity. Determine the spatial and temporal extent of the stratigraphic horizons of the study area. Determine stratigraphic relationships of these silty deposits to volcanic ash beds, caliche layers, or other geologic-age indicators.

This study will determine stratigraphic continuity of sediment layers in the vicinity of the discovery site of ancient remains as follows. Full-depth profiles of the exposed bank face will be hand excavated to provide smooth, fresh vertical exposures of the sediments at approximately 25-m intervals. The project schedule will allow for 14 such profiles. More or fewer profiles may be defined by the PI. The interval between profiles may be increased depending upon the degree of stratigraphic distinction. Samples also may be taken between the vertical profiles. Soil scraped from the profiles will be available to the non-Corps components of the team to be screened for separation of cultural resources. Some areas covered with trees and roots may be cleared with hand tools or with a chain saw. Local conditions may limit the number and location of exposed profiles.

Each vertical exposure should be a minimum of 50 cm wide, and will remain exposed until all have been revealed, so that features can be compared for the full length of the exposed bank. Each identifiable stratigraphic unit will be sampled (both bulk sample and acetate peel, if appropriate). All exposures will be photo- and audio/video-documented. Field descriptions will include grain-size characteristics, texture, color, bedding thickness and type, depth from terrace surface, and other standard field data.

To reduce disturbance at the site, clearing, profiling, recording, and sampling of these profiles will be coordinated with the Government Principal Investigator. The Walla Walla District will provide surveying support with GPS and other equipment as needed to create a base map of the study site with adequate positional control.

Feature continuity and shape. A soil auger will be used to confirm short-range continuity of visible features away from the exposed face into the bank for at least the width of the area likely to be covered or disturbed for bank stabilization. Soil cores will be taken using manually operated equipment. Cores will be placed at intervals back into the deposit away from the bank face and near the apparent edges of the deposit to reveal preliminary indicators of the 3-dimensional shape and stratigraphic continuity of the feature. Cores also will be taken into the sediments at and below the level of the vertical faces. Due to difficult weather conditions anticipated, cores will be shipped to the WES intact for detailed study. Cores will be photographed, examined, and described at the WES, after which samples from the cores will be provided to non-WES components of the study team. This augering and coring will involve no major disturbance to the site.

The Principal Investigator has tentatively located the eastern and western boundaries of the stratigraphic feature of interest at contacts with gravel materials that are readily differentiated from the silty material present at the site of the ancient remains. A soil probe or auger will be used to define these boundaries.

Ancient soil horizons and chronology. If ancient buried soil horizons (paleosols) are identified in the stratigraphic exposures, they may be critical to defining chronology and age of these sediments, as well as the landscape setting at the time of burial of the human remains. It will be essential to involve a soil scientist with local and regional experience to evaluate significance of paleosols and determine their age relationships. This will be critical if they are stratigraphically related to or younger than the horizon from which the human remains were removed.

Archeological assessment. The excavations will be limited vertical exposure of the bank, and some augering and soil coring. If conditions at the site warrant, additional, slightly larger tests within the area along the erosion face and within the area to be impacted by the stabilization project may be used. In any case, it is important to proceed cautiously, conscious of the possibility of encountering archaeologically or culturally significant items. The main focus of this task is to determine if other cultural resources are indicated in areas that would be covered by bank protection. If cultural resources are identified during the geologic and geoarcheological assessment of the exposed bank, standard archaeological field procedures for excavation and recording will be used to establish exact location and orientation of such items. Any archeological resources that are collected will be described and analyzed as part of the site investigation and curated by the Corps of Engineers. The artifacts will be made available to the ARPA permit holders upon written approval by the Principal Investigator (WES) for analyses they wish to undertake.

A limited assessment may be performed using non-invasive geophysical techniques between the top of the vertical reservoir bank and the water line, along that portion of the study site that will be covered by bank protection. At the discretion of the PI, a local contractor in the Tri-Cities area may be directed to conduct a limited survey during one day of the on-site activities, following WES requirements, with data to be provided to and interpreted by the WES.

The team is sensitive to the need to use careful documentation procedures for any cultural materials. If any cultural material is located, work will temporarily stop and the Principal Investigator will be notified. The Principal Investigator will then determine disposition of the cultural material. If human remains are encountered, they will be left in place. The Benton County Coroners office and appropriate tribal representatives will be notified of the find. If the remains are determined to come under the coroner's jurisdiction, no further project involvement will be required. If the human remains are determined to be Native American, all further actions taken with regard to the remains will be done in compliance with the Native American Graves Protection and Repatriation Act and Archaeological Resources Protection Act and in full cooperation with appropriate tribes.

Petrographic, geochemical, and radiometric analyses. Samples of all stratigraphic units will be collected. These analyses will be initiated immediately following the on-site work, and will include mineralogy, particle size analyses, geochemical analyses, and electron microscopy or other petrographic techniques as needed to differentiate among sedimentary units, paleosols, volcanic ash beds, and other identifiable stratigraphic features. Analyses will be focused on relating the characteristics of these features to published data from volcanic ashes, paleosols, and other features of known age identified previously in this region, to establish chronology. Limited analyses will be completed during these studies and included in the report.

The probability exists of encountering materials in the vicinity of the remains site that contain carbon and can be C-14 age dated. Materials for radiometric dating will be submitted to two laboratories simultaneously, so that no conclusions are based on a single measurement.

Conceptual model geologic setting and processes. All of the data from this study will be used to establish a conceptual model of the geologic and geomorphic processes that were active at the time the remains were incorporated into the sediments.

Schedule and Funding. All on-site work and sampling will be completed within 2 weeks of initiation of on-site study, unless delayed by weather conditions. Field work is scheduled between 10 and 23 December. Analyses of samples will require coordination with radiocarbon dating facilities. NRCS

laboratory facilities may be involved in these analyses. Data will be shared among all participants in the on-site study.

Records and Reports. Standard procedures and data sheets will be established for consistency among all team members in documentation such as field notes, drawings, and photography notes. Hand-written notes will be transcribed into WordPerfect files. Photographs will be taken with a digital camera or will be converted to digital files, for ease of sharing data among all agencies. WES will prepare a report of the results of the studies with input from all team members, incorporating the results of on-site investigations, summarizing the significance of laboratory analyses in meeting project objectives, and describing the conceptual geomorphic model for the site. This report also will summarize any differences in interpretation of the site geology and geoarcheology among the Government scientists and the ARPA permit participants.

Coordination and open exchange of information with the ARPA permit participants will be continuous throughout on-site investigations and data analyses. The scientific work will proceed appropriately in an open forum, with sharing and discussion of data.

WES Team Members. Project Leader, Dr. Lillian D. Wakeley, 601-634-3215. Team members, Mr. Joseph Dunbar, Mr. William Murphy, Dr. Andrew Warne, and Dr. Fred Briuer.

MEETING AT CORPS FACILITY, PASCO, WA
12 December 1997

Name	Affiliation	Phone
Manfred (Fred) Jaehnig	CTUIR	541-276-3629
Julie Longenecker	CTUIR	509-627-2944
Jeff Van Pelt	CTUIR	541-276-3629
Don Disbro	COE	509-543-3202
Gary Shea	COE	509-543-3260
Gary Huckleberry	WSU	509-335-4807
Dave Hays	COE	509-543-3263
Paul Nickens	DOJ	520-577-6024
Fred Briuer	WES	601-634-4204
Bill Murphy	WES	601-634-3322
Jim Baker	WW	509-527-7717
Gordon A. Lothson	YIN	509-865-6262
Pete Rice	CCT	509-634-4711, x546
Brent Hicks	CCT	509-634-4711, x546
Andrew Warne	WES	601-634-2186
Ray Tracy	WW	509-527-7270
Linda Carter	WW	509-527-7262
Dutch Meier	WW	509-527-7020
Barry L. Richards	WW	509-543-3264
Lillian D. Wakeley	WES	601-634-3215
Joe Dunbar	WES	601-634-3315

YIN = Yakama Indian Nation
CTUIR = Confederated Tribes of the Umatilla Indian Reservation
CCT = Colville Confederated Tribes
WW = Walla Walla District
WES = Waterways Experiment Station
DOJ = Department of Justice

Columbia Park Site Personnel
Phase Two Investigations
Kennewick Discovery Site
December 1997

Coordinated by Corps of Engineers	13 Dec	14 Dec	15 Dec	16 Dec	17 Dec	18 Dec
Anderson, Scott (CENWW)				X		X
Bergstrom, Kevin (CH2M Hill)				X		
Bondurant, Cliff (CENWW)				X		X
Briuer, Fred (CEWES)	X	X	X	X	X	
Carter, Linda (CENWW)	X	X		X	X	
Conway, Nola (CENWW)				X		
Dunbar, Joe (CEWES)	X	X	X	X	X	
Leier, John (CENWW)	X		X			
Marceau, Tom (DOE)					X	
Meier, Dutch (CENWW)			X	X		
Militello, Teresa (CEMVS)				X		
Miller, Roy (CH2M Hill)				X		
Mitchell, Tom (CH2M Hill)				X		
Murphy, Bill (CEWES)	X	X	X	X	X	X
Nickens, Paul (Dept. of Justice)	X	X	X	X		
Richards, Barry (CENWW)					X	
Tracy, Ray (CENWW)	X	X	X	X	X	X
Trimble, Michael (CEMVS)				X		
Wakeley, Lillian (CEWES)	X	X	X	X	X	
Warne, Drew (CEWES)	X	X	X	X	X	X
Wolfe, Aaron (CENWW)			X	X		
Wysocki, Doug (NRCS)				X	X	X

TOTAL: 22

Columbia Park Site Personnel
Phase Two Investigations
Kennewick Discovery Site
December 1997

Washington State University Permit	13 Dec	14 Dec	15 Dec	16 Dec	17 Dec	18 Dec
Ackerman, Robert					X	
Bonnichsen, Robson	X	X				
Chatters, Jim	X	X	X	X	X	X
Curewitz, Diane				X		
Danz, Jonathon				X		
Galm, Jerry					X	
Georgina, Dianna			X			
Gough, Stan					X	
Holmes, Amy	X					
Huckleberry, Gary	X	X	X	X	X	
Johnson, David		X	X			
Kramer, Katherine	X					
Lindsey, Emily					X	X
Petersen, Ken					X	
Reed, Ken				X	X	
Ross, Michelle		X				
Stafford, Tom	X	X	X	X	X	X
Wegener, Robert					X	
Wysocki, Don	X		X	X		

TOTAL: 19

Columbia Park Site Personnel
Phase Two Investigations
Kennewick Discovery Site
December 1997

CTUIR Permit	13 Dec	14 Dec	15 Dec	16 Dec	17 Dec	18 Dec
Barkley, Lloyd	X	X	X	X		
Fecht, Karl				X		
Foley, Mike		X		X		
Jaehnig, Fred	X	X	X	X	X	X
Jaehnig, Janice	X					
Lindsay, Kevin				X		
Longenecker, Julie	X	X	X	X	X	X
Patrick, Julius	X	X	X	X		
Reidel, Steve				X		

TOTAL: 9

Columbia Park Site Personnel
Phase Two Investigations
Kennewick Discovery Site
December 1997

Observers	13 Dec	14 Dec	15 Dec	16 Dec	17 Dec	18 Dec
Buck, Rex (W)	X				X	
Buck, Jason (W)	X					
Cadoret, Natalie (Battelle)						X
Cliff, Bernie (CTUIR)			X	X	X	X
Cliff, Alan (CTUIR)				X	X	X
Croswell, Debra (CTUIR)					X	
Harvester, Perry (S)						X
Hicks, Brent (C)				X	X	
Lenz, Brett (W)			X	X	X	
Lothson, Gordon (Y)	X	X	X			
Lyon, Jason (N)			X			
Minthorn, Armand (CTUIR)					X	
Rice, Pete (C)	X		X	X		
Sampson, Carl (CTUIR)	X					
Tomanowash, Robert (W)	X					
Tomanowash, Marie (W)			X	X		
Williams, J. D. (CTUIR)					X	

TOTAL: 17

N = Nez Perce
CTUIR = Confederated Tribes of the Umatilla Indian Reservation
W = Wanapum
C = Colville Confederated Tribes
Y = Yakama
S = Washington Dept of Fish and Wildlife

Appendix B

Discovery of Ancient Remains at
Kennewick Site
and Subsequent Events

Paul R. Nickens
Consulting Archaeologist

Discovery

The highly publicized discovery of human remains at the Columbia Park site was first reported in the 29 July 1996 edition of the *Tri-City Herald* under the headline "Skull found on shore of Columbia." That initial brief story told how two spectators at the annual hydro boat races being held at Columbia Park that weekend stumbled on a human skull on the muddy beach. One of the men involved in the discovery actually hit the intact cranium with his foot while wading about 10 ft offshore at a depth of about 18 in. Not wanting to miss the boat race finals, the two discoverers placed the cranium in the bushes along the shoreline, planning to return and explore the find later in the afternoon. Following the race, they returned to retrieve the skull and soon turned it over to a city police officer.

From this seemingly inauspicious beginning, the story of the Columbia Park human skeleton has sparked international interest, including litigation over the future of the remains between a group of scientists and the U.S. Government. For the interested, complete coverage of the sequence of events that have unfolded surrounding the ensuing controversy can be found online at the *Tri-City Herald* (http://www.tri-cityherald.com/bones/). As of August 1998, this web site archive included nearly 100 Herald articles chronicling activities related to this issue.

This review does not recount the entire story and does not delve into the administrative or legal matters. It examines what information exists about the condition, distribution, and location of the remains at the time of discovery and through the period of recovery. The period of discovery and recovery begins on 28 July 1996 and extends until 4 September 1996 when the human remains were transferred to control of the Corps of Engineers. However, bone elements/fragments continued to be discovered after that date. These later events are considered here as part of the overall recovery effort. Finally, this evaluation does not judge the circumstances or activities on the part of any individuals or offices of this period but documents them using the extant record.

Primary information related to the circumstances of discovery and recovery is contained in written notes and later statements made by the principals involved in the efforts during this period of time, and limited photographic documentation. As the responsibility for determining the future of the remains shifted from county representatives to the Federal Government, careful attention was given to acquiring these records from persons with specific activities in the recovery period. Consequently, copies of all primary field data and other associated documentation prepared during this time period are on file in the office of the U.S. Army Engineer District, Walla Walla (CENWW). In some cases, more recently generated information is used to supplement records regarding events of the earlier period.

The initial discovery by members of the recreational public was entirely inadvertent, and appropriately handled by the discoverers who contacted the local authorities. Once contacted, local police immediately took steps to delineate and protect the discovery area. According to police reports, within a few hours the area had been evaluated, the county coroner brought on scene, and an archaeological consultant contacted by the coroner.

Based on field observations by this author and following review of the existing documentation, it appears that the site exhibited the following characteristics at the time of discovery. The human skeletal remains were localized but dispersed over a rather larger area of the beach, perhaps as much as an area of some 300 sq ft or more. The heavier mud-filled cranium possibly marked the original horizontal location, but it was found some 4 to 5 m from where the edge of the bank was at the time of discovery. Contextual evidence indicates that the remains were probably at one time fairly compactly situated within the receding bank, at an unspecified level above the reservoir water line. Bank recession, which was very severe in both 1995 and 1996 along the Columbia River, at some time in the past caused the remains to be dislodged and collapse on to the beach, followed by dispersal of the individual elements over a larger area. It is easily conceivable that wave action, primarily caused by boat traffic, created the necessary energy to disperse the skeletal materials once they were introduced into Lake Wallula.

Exactly how long the remains were loose in the water cannot be determined. Typically, the operating level of the Lake Wallula pool fluctuates very little, meaning that the remains, once on the beach, were fairly continuously in a fairly wet environment. The good state of preservation of the individual bones at the time of discovery indicates that the remains were not extensively exposed to either ultraviolet or lengthy dry conditions while out of their original context.

Recovery Events

Following discovery of the human cranium by members of the public on 28 July 1996, more formal collection of individual skeletal elements was initiated later that same day. Inspection of the site at that time by the county coroner's consulting archaeologist resulted in the notation of both prehistoric and historic artifacts exposed as lag on the beach, but no cultural materials were observed in situ within the exposed cutbank. Skeletal materials collected from the beach that evening by the archaeologist, assisted by members of the Columbia Basin Dive Rescue team, included the following elements: right and left innominates, a sacrum fragment, distal left femur fragment, both proximal femora sections, six rib fragments, right humerus (in two pieces), the proximal portion of the right tibia, atlas, axis, two thoracic vertebrae, both malars, horizontal ramus of the right mandible, parts of both ulnae, and the distal portion of the right radius. At the time, the archaeologist made the observation that these elements were probably located in the original find spot, which presumably coincided with the

position of the cranium collected earlier in the day. All of these human remains were submerged in water when retrieved.

Because of the physical setting along the shoreline and the dispersed nature of the skeletal pieces, additional elements of the human skeleton continued to be collected during visits to the locale over the next few weeks. These events are briefly listed as follows:

29 July 1996 – The archaeologist returned to the site and retrieved a number of rib fragments, right ascending ramus, left distal radius, left ulna mid-shaft fragment, mid-shaft and distal part of the right femur, the mid-shaft of the left tibia and the proximal end of the right tibia, various hand and foot bones, and several vertebrae and scapula fragments.

31 July 1996 – The archaeologist visited the site to attempt collection of any remaining skeletal elements. The collection approach included sluicing and screening. Skeletal pieces retrieved at this time included the right horizontal ramus, seventeen rib fragments, a patella, proximal right radius fragment, five fibula fragments, including parts of both sides, three scapula fragments, the distal portion of the left tibia, nine vertebrae and fragments, a fragment of a clavicle, and the proximal portion of the left humerus.

2 August 1996 – The archaeologist checked the shoreline again on this date with negative results.

3 August 1996 – The archaeologist once again inspected the site and recovered three rib fragments and a small hand bone.

5 August 1996 – The archaeologist revisited the site on this day and once again performed sluicing of the beach sediments in an attempt to retrieve more of the skeleton. Positive results were achieved in the vicinity of the original find and the following skeletal elements were collected: midsection of the left femur shaft, distal right tibia, left calcaneous, right metatarsal, # 1 and 8 phalanges, two metapodials, left glenoid, right patella, left acromion, a vertebra, nine vertebrae fragments (thoracic and cervical), five fibula fragments, and thirteen rib fragments.

11 August 1996 – The beach was again checked by the archaeologist who found and collected additional rib fragments and some hand and foot bones.

19 August 1996 – The beach was checked by the archaeologist with negative results.

26 August 1996 – The archaeologist again examined the beach and found nothing.

29 August 1996 - The archaeologist, accompanied by one of the original discoverers, visited the site. Three small rib fragments were recovered as a result of this visit.

The above visits to the Columbia Park site by the archaeologist employed by the county coroner's office, 10 in all, comprise the formal attempts to collect the dispersed elements of the human skeleton. This effort was concluded with the Corps officially taking possession of the human remains from the coroner's office on 5 September 1996.

As part of these field visits, and under terms of the Archaeological Resources and Protection Act permit issued to the archaeologist by the Corps of Engineers, various prehistoric and historic artifacts were collected from the general beach area. All were noted as being "beach lag," meaning that all had eroded from their original locations and in situ contexts and were collected from an area along the beach covering some 25 m. The collection of artifacts was eventually turned over to the Corps of Engineers and subsequently analyzed by Sappington (1997). Sappington's letter report includes an inventory of the items, along with analysis and dating, where possible, of both prehistoric and historic period artifacts. Sappington's analysis indicates that eight of the artifacts (six flakes and two flaked basalt cobbles) are probably prehistoric, but these items are not chronologically distinctive and cannot be assigned to any particular time period. Historic artifacts include domestic refuse and faunal remains. None of the collected artifacts can be specifically associated with the human remains retrieved from the beach in the Summer of 1996.

In addition to the recovery activities completed by the county coroner's office personnel during the first 2 months following the initial discovery, later field visits to the site by various personnel resulted in actions that are considered to be part of the data recovery effort. In mid-September 1996, representatives of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) Cultural Resources Program visited the site and collected additional bone fragments, some of which were human and probably associated with the human remains under evaluation. The human bones collected by this activity included two foot phalanges, one hand phalange, four rib fragments, one vertebral spinous process, one possible pubis fragment, and eight miscellaneous bone fragments. These specimens were placed with those previously collected on 17 September 1996. Later in October of that fall, the CTUIR undertook field recording and mapping of the Columbia Park site (Jaehnig 1996). This effort resulted in a site form being prepared to include the discovery site. Although the presence of both human and non-human bone and prehistoric stone artifacts is noted in the written report and on the site map, it is not stated in the document whether or not collection of these items was completed.

On 11 November 1996, the archaeologist working for the coroner's office again visited the site, in the company of a Corps of Engineers archaeologist, for the purpose of collecting non-cultural soil samples. During this field visit, the

beach area was once again inspected with no additional pieces of human bones being observed.

Two more recent events conclude the recovery activities for cultural materials at the Columbia Park site. On 4 September 1997, a Corps of Engineers archaeologist encountered and retrieved a human left first metacarpal at the location. On 14 December 1997, a fragment of human rib was observed in the vicinity of the original discovery during the on-site geological investigations. Both pieces of bone are believed to be associated with the human skeleton under discussion and, in each case, were placed in the repository where the remainder of the materials reside.

Documentation of the above events related to the discovery of the human remains and subsequent recovery activities cannot, in many respects, be considered to include great detail. The initial discovery is well documented by written statements provided by police officers first on the scene, supplemented by a written statement provided by the Benton County Coroner. Written statements by Corps of Engineers personnel and others, including the archaeologist under contract to the coroner's office, are also available, having been filed as part of the court record. In general, these statements pertain more to the overall sequence of events and not the primary data needed for reconstruction of the field conditions. Data specific to the recovery activities are limited, and include brief hand-written notes made by the archaeologist involved and some photographs of the general discovery location. There are no maps, scaled or sketch, in the records that indicate general distribution or location of either human skeletal remains or artifactual materials collected from the beach.

Summary and Conclusions

Review of extensive published and unpublished information relative to past events at the Columbia Park site reveals a long historical cultural pattern of indeterminable length. Currently, the beginning for the sequence of cultural activities at this locale is the radiocarbon date associated with the human remains. Archaeologically, there is considerable indication that aboriginal peoples intensively occupied this general area over a long period of time. Available data indicate that this occupation intensified and is most evident over the past two to three millennia. Prior to the summer 1996 discovery of human remains here, there had not been archaeological materials identified at this specific location. However, the well-known archaeological site designated 45BN52 had been recorded about one mile upriver.

Evaluation of historical documents, maps, and photographs leads to the conclusion that the land where the human remains were located received relatively little impact over the past 150 years. This is especially true for activities that would have yielded disturbance of the ground. Other than the presence of the historic military trail that eventually became the concrete-paved River Road, these sources indicate that the tract has always been open and

undeveloped. According to Ms. Johanna (Austin) Colby, owner of the first residence to the east, prior to 1950 this particular tract of land between the river and the highway was too narrow to support a residence (personal communication, February 1998).

There is, however, field evidence that the open pasture area was used as a dumping ground for domestic refuse. The eroded beach today is strewn with fragments of glass, china, metal items, food bone, and construction materials (bricks and nails) debris. A sample of historic artifacts collected from this area indicates that much of the trash dates to the turn of the century, with some dating up to the 1940's (Sappington 1997). Although not investigated intensively, there is some indication in the cutbank near the location where the human remains were discovered that at least some of the trash may have been deposited in a pit, or at least dumped in a depression and covered over. Much of the animal bone evident, several pieces with butchering marks, are well preserved, indicating that they were buried before eroding out on to the beach as the bank has receded over the past few decades that the reservoir has been in place.

During the period since 1950, the land has been continuously included within the Columbia Park recreational area. It has apparently been allowed to revegetate itself and over time naturally became the wooded, brushy area that it is today. The only change in land pattern that is evident is the ongoing shoreline recession occurring along the water edge. Analysis of this erosion rate by comparing sequential historical aerial photographs by the U.S. Army Engineer Waterways Experiment Station (WES) indicates that some 15 m of horizontal loss has occurred since the inception of the reservoir.

The circumstances surrounding the initial discovery and subsequent recovery of the human remains are fairly well documented. Apart from the specific sequence of recovery actions, however, little documentary information is on file concerning the actual methods employed or the contextual conditions observed during the data recovery. It should be noted that in the cases of both human skeletal elements and other historic and prehistoric artifacts, none of these items was in situ at the time they were collected. Moreover, aside from some items of obvious relatively recent vintage, no cultural items have been located in situ in the immediate area of the original discovery location. The presence of clearly culturally derived materials occurring sporadically along the general beach area along this stretch of the shoreline, however, indicates both the presence of previously in place archaeological materials, as well as a potential for future such occurrences. The potential for direct relationship of any of these archaeological materials to the human remains is, at this point in time, problematical.

Acknowledgments

Several individuals provided assistance and data used in this analysis. David Harvey, Richland, WA compiled information used in the historic time line for

the project area (Chapter 3 of basic report), and contacted some former residents of the River Road area. Personnel at the CENWW office were especially helpful in providing information from their files and records, as well as answering innumerable questions. Corps employees who provided support to this effort include Lanell Adams, Jim Baker, Linda Kirts, John Leier, Lynda Nutt, and Ray Tracy. Lillian Wakeley and Joe Dunbar, scientists from the WES provided ongoing information about their findings from the geological field effort and copies of aerial photographs they procured from various sources. Special thanks are extended to Ms. Johanna Colby, former resident along the River Road, currently residing in Kennewick, WA and Mr. Robert Tomanawash, Wanapum Elder, residing at Priest Rapids, WA for their willingness to share memories about the project area.

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Appendix C

Excerpts from
Preliminary Report of the
Archaeological Component to the Geologic Investigation
of the Discovery Site of Ancient Remains,
Columbia Park, Kennewick, WA
by Frederick L. Briuer, PhD
Director, Center for Cultural Site Preservation Technology
2 January 1998

At the easternmost part of the site about 100 m south of profile CPP 005 on a high promontory, suggesting a very old and stable landform, was a concentration of small and large cobbles of quartz, basalt, and other minerals suggesting human modification. The promontory had about a 300 degree view and lay midway between the park road to the north and the highway to the south. Several large cobbles displayed multiple flake scars indicative of testing and initial knapping associated with possible lithic procurement and the first stages of lithic reduction. No small, well-made tools were observed, only large core and flake specimens. The probable artifacts seemed concentrated on the top of the promontory rather than the slopes where colluvial processes have exposed an even greater number of smaller pebbles and cobbles, mainly lacking indications of knapping. An old stable alluvial fan up out of the Columbia River flood plain but close to the advantages of that riparian environment may have been a very desirable location for prehistoric occupation. An occupation at the base of this promontory could also have offered some degree of protection in winter from prevailing southwestern winds. It is recommended that this area be recorded and more closely investigated.

While clearing vegetation and flood detritus at the eastern most profile location nearest to the zero point in the site base line, a large (ca. 900 grams) grainy basalt unifacial core tool was found in the draw down zone at the base of the cut bank 2.75 meters west of profile CPP 005. In all probability the large core tool had eroded out of the cut bank. The location of the stone tool on the active erosion surface in and among recent flood debris clearly indicates secondary deposition and removal from its primary stratigraphic context. There is no way to know its original position with respect to the stratigraphic profile investigated. Dr. Nickens photographed the artifact and described it in his field notes. The artifact was then returned to its place of discovery. Profile CPP 005 contained small charcoal and small shell fragments in the screened sediment from 20-80 cm. Closer examination of larger shell specimens in situ in the bank suggests possible midden deposit and the potential for radiocarbon dating of samples taken to WES. No other obvious cultural features or cultural stratigraphy were observed.

With the possible exception of one specimen of fish bone (CPP 044, 0-20 cm) the two profiles nearest the location of the original skeleton find (CPP 044 and CPP 054) were without prehistoric archaeological indications. The fish bone could be a product of natural processes having nothing to do with past human activity. To either side of profile CPP 054 were clear indications of historic trash pits and an approximately 15 m long scatter of late Nineteenth and Early Twentieth Century artifacts that have washed out of the cut bank. The historic artifact assemblage includes metal car parts, wire, a railroad spike, various sherds of plainware and transfer pattern ceramics, glass, plastic, tar, a pearlware canning insert fragment, and crockery fragments. Profile CPP 054 was thought by geologists Drs. Warne and Huckelberry to be an old stable

sediment despite the clear indications of an historic trash pit less than one meter to the west in the cut bank. Within the outline of the clearly delineated trash pit and in situ in the wall was the right angled corner of a cement paving stone. In the same trash pit also in situ in the wall were three articulated bones (distal left femur, patella and epiphysis of the proximal tibia) of what is probably a cow.

Enough of the bones were exposed to allow Ms. Longenecker to compare them with comparative specimens of both horse and cow. The elements compared favorably with cow but because of the great similarity in morphology one cannot necessarily rule out Bison. Ms. Longenecker would not agree to the suggestion that the bones be removed so that they could be compared to a Bison comparative specimen. She insisted that the bones remain in place. Dr. Briuer did closely examine the patella and found it to have the appearance of modern bone suggesting high organic content and lacking any clear signs of significant mineralization. The reddish color of the patella graded to a mottled tan color and had a greasy, waxy, texture suggesting the presence of residual bone grease. It is however recommended that before site protection work begins and the trash pit is made inaccessible, that the bones be removed for clarification regarding the Bison question.

Profile CPP 088 at 140-160 cm contained a few specimens of intrusive historic materials (wire, plastic, and aluminum) and recent vegetation detritus indicating some very recent secondary deposition from the above bank to the base of the profile where wave action, erosion, and gravity could account for the repositioning of modern material. In the level below this (160-180 cm) no historic or modern materials were encountered in the profile or screens. A bone fragment 1.2 cm long by .5 cm wide was recovered from the screen. The bone appeared burned, particularly on the outside. The size, color, and texture of the fragment did not compare well with the purported cow bone in the trash pit. Under low powered magnification, small striations parallel to the long axis of the fragment could be seen. There were no obvious signs of polishing or flaking indicating intentional human modification although both ends indicated breaks, possibly accidental. The fragment was neither fish nor bird. The curvature of the bone and the thickness of the pereosteum indicate a long bone fragment of a small sized mammal. There was no indication that this particular level was disturbed. Since this level is closest to the probable level where the skeleton is thought to have been associated, one cannot rule out a possible stratigraphic relationship. If a sufficient amount of organic material is available, it is recommended that the bone fragment be radiocarbon dated. Dating the bone fragment may help answer questions about the dating and integrity of the stratigraphic profile at this critical location. A radiocarbon date may also support an alternative explanation of secondary deposition.

Nothing of cultural significance was observed in profiles CPP 093 and CPP 125. Profile CPP 166 contained small mussel shell fragments throughout the upper four levels (0-80 cm), more shell fragments than had been observed in all

previous profiles. At 80-140 cm, shell fragments were absent. At 160 cm three pieces of basalt were observed, two in situ in the wall and one in the screen. Two of these, in the view of Dr. Briuer, were artifacts with evidence of human workmanship in terms of bulbs of percussion and/or striking platforms while the third specimen was questionable. This view was supported by Dr. Nickens, Dr. Rice, and others who had the opportunity to examine them. Dr. Jaehnig did not concur with the other archaeologists on this interpretation.

Dr. Warne, who examined two of the flakes in situ, thought that the entire profile had stratigraphic integrity. The profile at 160 cm lacked clear signs of recent secondary deposition that might account for the basalt flakes having fallen from above and being repositioned by recent fluvial processes. Dr. Huckleberry also thought the profile was intact at 160 cm and showed no obvious post depositional evidence but not having seen the flakes in situ suggested that an alternative secondary deposition must still be considered an open question.

Since this stratigraphic position is nearest to the presumed or probable stratigraphic position of the skeleton, one cannot at this time dismiss a possible stratigraphic relationship suggesting nearness in time between the human skeleton and the artifacts. At the same time, one cannot categorically dismiss the possibility of stratigraphic mixing. On the basis of the existing evidence, these two alternatives must remain open questions. The possibility of dating the bone fragment found at 160 cm in CPP 088 should contribute additional evidence to suggest one or the other explanations.

The artifacts, once cataloged, described, and photographed, were returned to their original place of discovery as agreed to in the prework conference.

Profile CPP 200 contained small shell fragments at 80-120 cm and again from 140-160 cm, which in itself is not very convincing evidence of human activity, since non-cultural processes such as predatory animals or fluvial deposition processes could be potentially the responsible agents for depositing some shell in a profile. However, upon closer examination of the bank 2.8 m east of the upper left hand corner of profile CPP 200, a stratified shell midden was observed. The upper level of shell was 36-50 cm from the top of the bank. The lens was over 2 m in width and consisted of many complete or nearly complete bivalves among many highly fragmented, poorly preserved shell specimens. Many of the shells showed a high degree of horizontal or near horizontal imbrication. Below that shell lens was a second distinct, but thinner layer (5 cm thick) and less continuous than the upper layer. Samples of both lenses were taken for laboratory examination and dating. In the process of screening these samples, one specimen of fire cracked basalt 4.2 X 3.4 cm was found in the screen. The specimen had a reddish cortex and a thin reddish rind and red color gradation towards the center of the specimen, characteristic of thermal modification. In addition, the specimen displayed the high angle of fracture and spalling characteristic of subjection to high heat and thermal shock.

The specimen was described, drawn, and photographed before being returned to its original place of discovery.

Dr. Briuer requested Dr. Chatters to identify the mussels from this location, if possible. Dr. Chatters preliminarily identified the species as Margaritifera falcata (fresh water pearl mussel) and Gonidea angulata (rocky mountain ridge back mussel). In the process of selecting the largest and best preserved bivalves for bagging and laboratory identification, it was noticed that charcoal was preserved and encased under two separate shells. The well preserved bivalves appeared to fortuitously create a microenvironment conducive to charcoal preservation. With the exception of the shell encased charcoal, no other obvious specimens of charcoal were observed in the two layers of the midden. Having fortuitously found well preserved charcoal presents an excellent opportunity for independent dating to complement problematic radiocarbon dates on shell.

With the exception of small shell fragments at 80-120 cm and 140-160 cm, nothing of potential cultural significance was observed in profile CPP 200. One cannot rule out non-cultural processes responsible for the accumulation of such small quantities of mussel shell observed in profile CPP 200. At the same time, one cannot rule out human agency either. It seems very unlikely that non-cultural processes could be responsible for the accumulation of much larger quantities of stratified and better preserved shell clearly associated with fire cracked rock and charcoal observed just 2.8 m from the profile. The likelihood of cultural processes being responsible ought to be commensurate with the quantity of the shell assemblage as well as the conjunction and diversity of other associated cultural indicators.

The only possible cultural indications in CPP 233 were small amounts of shell fragments observed in levels 20-40 cm and 60-80 cm. Small fragments of carbonized material found at 20-40 cm were the only possible cultural indicators found in CPP 268. A more probable explanation for charred remains found toward the top of this profile, CPP 296 and others, would be modern grass, brush, or root fires, particularly in view of the lack of other cultural indications.

On the last day of archaeological field work, as it was beginning to get dark, important cultural observations were brought to the attention of Dr. Briuer. Between profile CPP 268 and 296, a prehistoric flake and tool scatter was observed and preliminarily recorded. The scatter was confined to the active flood zone perhaps 15 m in length and ending about 10 m west of profile CPP 268. Although the cultural material was within 5 m of the cut bank, there was no evidence that any of it was eroding from the bank. The materials were also not eroding out of the clay on which they were immediately resting. All materials seemed to be secondarily deposited by recent fluvial processes. Among the flakes and tools were a large number of modern, recently introduced non-native mussel shells. The origin of the lithic materials was uncertain and may have been introduced as part of recent fill used for bank stabilization or path

construction. The possibility also exists that the artifacts could have washed from downstream from a source west of these two profiles.

Included in the assemblage were basalt flakes, both interior and cortical, quartz and quartzite flakes, and at least one flake of a fine-grained highly silicious material suggesting red jasper. One very fine-grained homogeneous obsidian flake was observed. Some flakes and cores appeared to have been fire cracked, one suggested battering indicative of a hammer stone. One quartzite unifacial flake tool had a cortical rind of calcium carbonate, indicating that it had once been on the surface for a long period. Two incomplete projectile points of basalt were observed. One of the points was a medial fragment, the other appeared to be a basal fragment with a flake or flakes missing from the actual base. Both appeared to be long and leaf shaped in form and cross section, but showed no obvious signs of edge grinding. The flake patterning was intricate. Dr. Chatters kindly made drawings of the two projectile points. After notes were taken, the artifacts were returned to their place of discovery and flagged with yellow PVC pin flags.

Appendix D

Profile and Core Descriptions from
Phase Two Study,
Kennewick Site

GEOARCHEOLOGICAL BANK PROFILE LOG

GEOARCHEOLOGICAL BANK PROFILE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP005	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 345.2 ft	Exposure Coordinates: 2336957E 328356N ft NAD27	Sheet 1 of 2 Sheets
Person(s) Preparing Field Excavation Log: A.G. Warne & L.D.Wakeley	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes		Methods used to Prepare Exposure: Hand Trowel		Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne		Attendant Archeologist(s):			Attendant Soil Scientist(s):	

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			2.5Y 3/2 mottled 2.5Y 5/3 (v dark gray-brown)	0-8 cm. Silt loam, organic material common, abundant fine roots, also tree roots. Bioturbated Rare qtz pebbles. Reacts with HCl. Contact with underlying unit gradational.	A Horizon	Topsoil		0-8	
10			2.5Y5/3 and 5/4 (light olive brown)	8-74 cm. Silt loam to loam, matrix reacts faintly with HCl. Extensively mottled.	Bt1			8-74	Holds vertical face but not strong ledge former (ledge in unit below)
20						Floodplain, backswamp, and marsh			No concretions
30									
40									
50									

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP005	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 2 of 2 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60			2.5Y5/3 and 5/4 (light olive brown)			Floodplain, backswamp, marsh				
70				Sharp contact at base. Occasional bivalve shell fragments near base.						Pronounced ledge at contact
			2.5Y5/3 (grayish to light olive brown)	74-121 cm. Fine sandy loam, with lighter colored mottling. Also darker mottling. (10YR3/2). Ledge formed at this level. Root zone with slightly gleyed aura near 100 cm. Lower unit is natural ledge former. No reaction with HCl.					74-121 cm	C14 date at 74 cm.
80				Small tephra included in this unit below shell fragments.		Levee, aeolian				
90										
100					Bt2					
110				Softer, more abundant mottles, notable root zones.						
				Base of section 121 cm.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP044	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 346.3 ft	Exposure Coordinates: 2336829E 328357N ft NAD27	Sheet 1 of 3 Sheets
Person(s) Preparing Field Excavation Log: A.G. Warne & L.D.Wakeley	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes			Methods used to Prepare Exposure: Hand Trowel	Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good	
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne			Attendant Archeologist(s):		Attendant Soil Scientist(s):		

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			2.5Y3/2 (v. dark grayish brown)	0-11 cm. Loam, A horizon, organic, abundant fine roots, medium roots common. Weak reaction to HCl.	A Horizon	Topsoil		0-11	Section sampled in 20 cm intervals the length of section on 12/16/97
10				Contact with underlying unit gradational.					
			2.5Y5/3 (grayish to light olive brown)	11-27 cm. Very fine sandy loam. Hard and dense, moderate fine mottling,. Mod. reaction to HCl.	Bk1			11-27	Ledge former at top of terrace.
20				Contact with underlying unit gradational.		Levee, aeolian			
30			2.5Y6/2 to 4/3 (light brownish gray to olive brown)	27-73 cm. Fine sandy to silt loam, extensively and finely mottled. Mottles darker. Moderate reaction to HCl.	Bkg2			27-73	Preferentially eroded to undercut terrace top. Possible tephra at 38 cm (Huckleberry)
40									
50									

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP044	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 2 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60										
70			5Y5/2 (olive gray)	73-77 cm. Fine silt, dense, with concretions. Abundant fine nodules. Strong reaction to HCl.	Bkg3				73-77	Forms ledge.
80			2.5Y5/3 (grayish to light olive brown)	77-182 cm. Silt loam, 2mm concretions abundant. Mottled. Abundant insect burrows. Concretions and mottling decrease with depth. Moderate reaction to HCl.	Bk4	Floodplain, backswamp, marsh			77-182	Insects assumed to be source of mottling.
90										
100				Change to silt loam to loam at 100cm. Less $CaCO_3$.						Profile extended down through ledge.
110										

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP044	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 3 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120				Silt loam to loam. very faint reaction to HCl						
130					bk4					
140			2.5Y5/3 (grayish to light olive brown)			Floodplain, backswamp & marsh				
150										
160										Ground surface, (terrace) at 160 cm
170										Pit at base continues into next terrace layer.
182				Base of profile 182 cm.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP054	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 346.7 ft	Exposure Coordinates: 2336797E 328366N ft NAD27	Sheet 1 of 3 Sheets
Person(s) Preparing Field Excavation Log: A.G. Warne & L.D.Wakeley	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes			Methods used to Prepare Exposure: Hand Trowel		Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne			Attendant Archeologist(s):			Attendant Soil Scientist(s):	

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			10YR4/3 (brown)	0-9 cm. Sandy loam, abundant organics. Abundant fine plant roots typical. Top soil, undulating but sharpcontact with unit below.	A Horizon	Topsoil		0-9	Top (A) section of three sections. Base of exposure A is 24 cm above exposure B, using line level. Exposure A extends approximately 20 cm.
				9 to 12 cm. Weak reaction to HCl.					
10			5Y4/3 (olive)	9-67 cm. Fine sandy loam. Extensively mottled. Abundant small, weakly developed concretions. Moderate reaction to HCl.				9-67	
20				Concretions are not well formed, suggesting they are next stage of mottling. 2-3 mm diam.	Bkg1	Levee, aeolian			
30									
40				40-60 cm. Mazama ash faintly visible.					Bioturbated
50									

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP054	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 2 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60			5Y4/3 (olive)	67-73 cm. Loam. Concretionary layer. Reacts vigorously with HCl.						
70			2.5Y4/3 (grayish to olive brown)	73-87cm. Silty loam, concretions common. Vigorous reaction to HCl. Concretions up to 5 cm. diam.					67-73	Ledge former
80					Bkg3	Floodplain, backswamp			73-87	
90				Gap in section at about 87 cm where profile is offset.						
			2.5Y4/3 (grayish to olive brown)	92-130 cm. Silt loam (continued from above), with concretions common to 1mm diam. Lighter mottling.	Bkg4				92-130	Exposure B of profile starts here.
100										
110										Extensively bioturbated

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP054	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 3 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120				Concretions and HCl reaction decrease downward, moderate at 95 cm, weak by 135 cm.	Bkg4					
130			5Y4/3 (olive)	130-144 cm. Sandy clay loam. Weak reaction to HCl. Few scattered small (1-2 mm) concretions.	Bk5				67-73	
140			2.5Y4/3 (grayish to olive brown)	144-168 cm. Silty loam. Weak reaction to HCl. Forms second step ledge.					73-87	Top of lower terrace (C exposure).
150					Bk6				92-130	
160										Extensively bioturbated
170			2.5Y4/3 (grayish to olive brown)	168-183 cm. Silty clay loam, soft (textural change). No reaction to HCl. Base of section at 183.	Bt7					Forms surface of beach.

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG

Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP080	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 346.3 ft	Exposure Coordinates: 2336715E 328369N ft NAD27	Sheet 1 of 3 Sheets	
Person(s) Preparing Field Excavation Log: A.G. Warne & Ray Tracy	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes	Methods used to Prepare Exposure: Hand Trowel	Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good			
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne	Attendant Archeologist(s):	Attendant Soil Scientist(s):					

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			10YR3/2 (very dark grayish brown)	0-9 cm. Sandy loam, organic, abundant fine roots, typical topsoil.	A Horizon	Topsoil		0-9	This exposure is immediately adjacent to a 20th century trash pit, portions of profile may be disturbed
10			2.5Y4/4 (olive brown)	9-27 cm. Sandy loam, platy ped structure. Rather dense. Moderate reaction to HCl.				9-27	
20						Levee, aeolian			
				27-35 cm. Loam, few irregular concretions. Moderate reaction to HCl.				27-35	
30			2.5Y4/4 (olive brown)						
			2.5Y5/4 (light olive brown)	35-43 cm. Same as above with possible tephra (tephra color is 2.5Y7/2 light gray).				35-43	CaCO3 concretions common in ash layer between Profile 080 and 093
40				43-97 cm. Silt loam, concretions common (2 - 10 mm diam). Strong reaction to HCl.				43-97	
50			2.5Y5/3 (light olive brown)			Floodplain backswamp, marsh			

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP080	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Tracy	Sheet 2 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60			2.5Y5/3 (light olive brown)	62-64 cm. Concretion layer, possible hiatus at top.						
70										
80										Extensively bioturbated
90										
100			2.5Y5/3 (light olive brown)	97-141 cm. Silty clay loam, faintly but extensively mottled. This unit forms a minor bench.					97-141	
110			2.5Y6/3 (light yellowish brown)	Weakly reactive to HCl. Few concretions up to 15 mm diam. Concretionsare weakly reactive to HCl.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP080	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Tracy	Sheet 3 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			2.5Y6/3 (light yellowish brown)	Some concentration of concretions at 124 cm.						
130										
140				Base of exposure 141 cm.						
150										
160										
170										

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP093	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 345.9 ft	Exposure Coordinates: 2336667E 328375N ft NAD27	Sheet 1 of 2 Sheets
Person(s) Preparing Field Excavation Log: A.G. Warne	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes		Methods used to Prepare Exposure: Hand Trowel		Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good	
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne		Attendant Archeologist(s):			Attendant Soil Scientist(s):		

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			10YR3/2 (very dark grayish brown)	0-9 cm. Sandy loam, organic, abundant fine roots, typical topsoil. Bottom contact gradational.	A Horizon	Topsoil		0-9	Entire section sampled in 20 cm increments on 12/17/97. Archived at WES
10			2.5Y4/3 (grayish to olive brown)	9-28 cm. Fine sandy loam, faintly but extensively mottled. A few small concretions (1-3 mm). Weakly reactive to HCl.	Bk1			9-28	
20						Levee, aeolian			Extensively bioturbated
				28-37 cm. Fine sandy loam, extensively mottled. Lighter mottles. Highly reactive to HCl. Extensive concretions in lower half (5-10 mm diam). Contains Mazama ash.				28-37	
30					Bkg2				
40			2.5Y4/3 (grayish to olive brown)	37-92 cm. Silt loam, extensively mottled. Moderate reaction to HCl. Concretions common (5-10 mm). Root casts common. (12/18/97) Lighter mottles caused by Fe depletion along burrows and root channels.	Bkg3	Floodplain, backswamp, marsh		37-92	12/18/97 Clay films ~ 5 mm thick, crenulated, discontinuous. Most pronounced one is ~ 2-3 cm below ash, 3 or 4 more within 17 cm below ash.
50									Bioturbated

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP093	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 2 of 2 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60			2.5Y4/3 (grayish to olive brown)	57-61 cm. Concretion layers, suspected hiatus at top.		Floodplain, backswamp, marsh				
70				Fewer concretions with depth.	Bkg3					
80										Extensively bioturbated
90				Contact is gradational.						
				92-130 cm. Silty clay loam. Wery weak reaction to HCl. Soft, forms bench. small open tubes are common. Mottling is apparent.	Bk4				92-130	
100			2.5Y4/2 (dark grayish brown)			Floodplain, backwater swamp, marsh				
110										Extensively bioturbated
130				Base of exposure 130 cm.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG

GEOARCHEOLOGICAL BANK PROFILE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP125	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 346.0 ft	Exposure Coordinates: 2336559E 328382N ft NAD27	Sheet 1 of 3 Sheets
Person(s) Preparing Field Excavation Log: A.G. Warne & L.D.Wakeley	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes			Methods used to Prepare Exposure: Hand Trowel		Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne			Attendant Archeologist(s):			Attendant Soil Scientist(s):	

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			10YR3/4 (dark yellowish brown)	0-6 cm. Silty loam, organic. a tree root traverses the face. Bottom portion bioturbated.	A Horizon	Topsoil		0-6	
			2.5Y3/2-4/2 (dark grayish brown)	6-9 cm. Bioturbated interval. fine sandy loam. Moderate reaction to HCl. Macropores common.					
10			2.5Y4/3 (grayish to olive brown)	9-26 cm. Fine sandy loam. Concretions increase downward. Moderate reaction to HCl.	Bk1			9-26	
20						Levee, aeolian			
			2.5Y4/3-7.2 (grayish to olive brown)	26-31 cm. Rhizo-concretionary layer. Concretions 2-20 mm in diam. Moderate reaction to HCl.				26-29	26-31 cm. supported by concretions, not by matric
30			2.5Y4/3-6/2 (light brownish gray)	31-51 cm. Silt loam, mottled. Mottling appears to be concentrations of CaCO3, 2-3 mm diam.				29-93	
40					Bkg2	Floodplain, backswamp, marsh, distal levee			
50			2.5Y4/3-6/2 (light brownish gray)	51-93 cm. Silty clay loam, mottles.	Bkg3				Bioturbated

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)

Project:	Location:	Exposure ID:	Date:	Site Coordinator:	Log recorder:	Sheet 2
Ancient Remains	Kennewick, WA	CPP125	12/14/97	L.D. Wakeley	Warne, Wakeley	of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60			2.5Y4/3-6/2 (light brownish gray)	51-93 cm. silt, mottles.						
70										Extensively bioturbated
80						Floodplain backswamp, marsh, distal levee				
90			2.5Y4/3 (grayish to olive brown)	93-97 cm. Concretionary layer (3-20 mm) with concretions in place. Moderate reaction to HCl.	Bkg4	——			93-97	
100			2.5Y4/4 (olive brown)	97-112 cm. Silty loam, with concretions common. Moderate reaction to HCl. Concretions up to 20 mm.	Bk5	Floodplain backswamp, marsh				
110				112-170 cm. Silty clay loam, soft, bench former, mottled. No reaction to HCl. Mottles faint but extensive.	Bk6				112-170	May be top of ledge. Not sure material is in situ. May be slump. May be filled in (mat'l out of place relative to areas east and west).

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP125	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 3 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			2.5Y4/4 (olive brown)	Silty clay loam as above.						
130						Floodplain backswamp, marsh				Extensively bioturbated
140										
150					Bk6					
160										
170				Base of exposure 170 cm.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG

Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP166	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 346.4 ft	Exposure Coordinates: 2336423E 328400N ft NAD27	Sheet 1 of 3 Sheets
Person(s) Preparing Field Excavation Log: A.G. Warne & L.D.Wakeley	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes	Methods used to Prepare Exposure: Hand Trowel	Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good		
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne	Attendant Archeologist(s):	Attendant Soil Scientist(s):				

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			2.5Y4/2 (dark grayish brown)	0-8 cm. fine sandy loam, organic. Fine roots common.	A Horizon	Topsoil		0-8	Much sandier than other profiles. Large animal burrows throughout column to base. Indicates dryness.
10			2.5Y4/3 (grayish to olive brown)	8-12cm. Fine sandy loam with organic staining. Medium roots common.				8-12	
20			2.5Y5/3 (gray to light olive brown)	12-63 cm. Fine sandy loam, homogeneous, mildly to moderately reactive to HCl. Scattered small concretions, 2-4 mm. Soft, erodible.	Bk1	Levee aeolian		12-63	Loose, no clay. Different from other areas. Much drier than 125 (further from drainage.
30									
40									
50									

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP166	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 2 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60–77			2.5Y5/3 (dark grayish brown) 5Y4/2 (olive gray) 2.5Y7/2 for blocks, pieces.	63-77 cm. Calcrete layer (well cemented). Mild reaction to HCl. Ledge former, Concretions are irregular to blocky pieces. May be reworked tephra. Sandy texture when broken. Tabular structure to "concretions". Matrix is silt loam. Reacts strongly to HCl.	Kg2				63-77	Could be silcrete or reworked tephra. Strong ledge former.
77–114			2.5Y4/2 (dark grayish brown) to 2/5Y6/2 for mottles.	77-114 cm. Silt loam with scattered, poorly developed concretions forming lighter mottles. Otherwise homogeneous. Reacts strongly to HCl on lighter colored mottles.	Bk3	Floodplain backswamp, marsh, distal levee			77-114	Continues as ledge former. Bioturbated
114–			2.5Y4/2 (dark grayish brown)	114-153 cm. Silty clay loam, homogeneous, no concretions. Reacts weakly to HCl.	Bt4	Floodplain backswamp, marsh,			114-153	Retains ledge formed by units above.

Depth scale: 60, 70, 80, 90, 100, 110

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP166	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 3 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			2.5Y4/2 (dark grayish brown)	Silty clay loam as above.		Floodplain backswamp, marsh				Bioturbated
130					Bt4					
140										
150				Base of profile 153 cm.			L			Three lithic fragments recovered at base of profile. Large animal burrows at base.
160										
170										

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG

GEOARCHEOLOGICAL BANK PROFILE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP200	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 347.0 ft	Exposure Coordinates: 2336321E 328436N ft NAD27	Sheet 1 of 3 Sheets
Person(s) Preparing Field Excavation Log: A.G. Warne & L.D.Wakeley	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes			Methods used to Prepare Exposure: Hand Trowel	Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good	
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne			Attendant Archeologist(s):		Attendant Soil Scientist(s):		

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			10YR2/2 (very dark brown)	0-7 cm. Silty fine peat, organic. Weak reaction to HCl. Abundant fine and medium roots.	A Horizon	Topsoil		0-7	Shell midden ~ 5m downstream of profile extends from approxiimately 10 to 60 cm depth
10			10YR4/3 (brown)	7-14 cm. Sandy loam with fine to medium roots common. Dark staining from topsoil above.				7-14	
20				14--59 cm. very fine sand. faint bedding visible. Few scattered small concretions (2-4 mm). Strong reaction to HCl.				14-59	Possible aeolian sand.
30			10YR4/3 (brown)			Levee aeolian			Mammal burrows extend to 45 cm depth, stop abruptly.
40									Extensively bioturbated
50									

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP200	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 2 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60–70			2.5Y4/3 left, 2.5Y5/3 to 10YR5/4 right (olive brown to yellowish brown)	59-78 cm. Indurated silt left side of profile. Contact abrupt and highly irregular. Moderate reaction to HCl. Complexly interbedded with silt loam. Reacts strongly with HCl. Extensively burrowed, with fine to medium bioturbation. Extensively mottled.	Bkg2	Too lithified to determine			59-78	Reworked ash "fragments" below indurated zone at 59-69 cm.
70–80									78-92	Matrix-supported. Strong reaction to HCl around clay tubes, but clay reacts weakly.
80–90			2.5Y5/3 (grayish to light olive brown), 2/5Y6/3 for mottles.	78-92 cm. scattered clay tubes up to 15 mm diam. (like clay pebbles). Silt loam matrix. Clay tubes subangular. Clay tubes start at 78 cm. Clay balls react weakly to HCl. 10YR4/3 clay pebbles.	Bk3	Floodplain, backswamp, marsh, distal levee				
90–100			2.5Y5/3 (grayish to light olive brown),	92-100 cm. Indurated silt or concretions. Some react with HCl. 15 mm and larger concretions are the type that form lag deposits on beach. Silt loam. Mottled to 2/5Y7/2.	Kg4				92-100	Matrix supported.
100–110			2.5Y5/3 (grayish to light olive brown) to 2.5Y6/3 for mottles.	100-121 cm. Silt loam, with very fine, scattered concretions (~2 mm), finely mottled. High to moderate reaction to HCl.	Bk5				100-121	Appears massive. Concretion layer hides. Bioturbated
110										

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP200	Date: 12/16/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 3 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			2.5Y5/3 (grayish to light olive brown) con'd	121-166 cm. Silty clay loam. Weak reaction to HCl	Bk6					No obvious breaks in slope.
130						Floodplain backswamp, marsh				12/17/97. Note: shell layer cast of this profile, 2-5 m. Bioturbated
140										
150				Base of profile 166 cm.						
160										
170										

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP233	Type of Exposure: (bank, trench, etc). bank	Elevation at Top of Exposure: 346.4 ft	Exposure Coordinates: 2336237E 328482N ft NAD27	Sheet 1 of 3 Sheets
Person(s) Preparing Field Excavation Log: A.G. Warne & L.D.Wakeley	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes			Methods used to Prepare Exposure: Hand Trowel	Width of Exposure: 50 cm		Height of Exposure: 124 cm	Quality of Exposure: Good
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne			Attendant Archeologist(s):			Attendant Soil Scientist(s):	

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			10YR3/2 (very dark grayish brown)	0-7 cm. Sandy loam. Abundant fine and medium roots. A horizon organics.	A Horizon	Topsoil		0-7	
10			2.5Y5/4 (yellowish brown)	7-50 cm. Fine sandy loam, fairly homogeneous. Scattered small concretions, 3-5 mm. No pore framework. Weak reaction to HCl.				7-49	12/18. Possible pestel found ~10 m downstream of CPP233; photos taken.
20					Bki	Levee, aeolian			No concretions
30									
40				Subtle, irregular contact with unit below.					
50			2.5Y4/4 (light brownish gray)	49-88 cm. sandy loam with fine concretions and pores. No reaction to HCl.	Bkg2			49-88	Erodes back relatively easily.

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP233	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 2 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60–88 (60, 70, 80)			2.5Y4/4 (light brownis gray) con'd		Bkg2	Levee aeolian				
88–109 (90, 100)			2.5Y4/3 (grayish to light olive brown),	88-109 cm. Concretions increase to common. Silt loam. More erosion resistant. Concretions 3mm to 2 cm. Reacts strongly to HCl.	Bkg3	Floodplain backswamp, marsh distal levee			88-109	Concretions not abundant on strand. Bioturbated
109–125 (110)			2.5Y5/4 (light olive brown) w/ 2.5Y7/2 mottles.	109-125 cm. Silt loam Fine mottles distinct. Abundant fine pores. Reacts strongly to HCl.					109-125	

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP233	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 3 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			2.5Y5/4 (light olive brown) w/2.5Y7/2 mottles	Very irregular contact.	2Bkg3					
				125-132 cm. Soft clay, no mottling, some silt. Homogeneous. No reaction to HCl.						Erodes more easily than layer above.
130			10YR4/3 (Dark brown)	132-176 cm. Clay loam, homogeneous. No reaction to HCl.	Bt	Floodplain backswamp, marsh				Slightly harder and more erosion resistant than unit above.
140										Extensively bioturbated
150										
160										
170				Base of profile 176 cm.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP268	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 346.2 ft	Exposure Coordinates: 2336127E 328546N ft NAD27	Sheet 1 of 3 Sheets

Person(s) Preparing Field Excavation Log: A.G. Warne	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes	Methods used to Prepare Exposure: Hand Trowel	Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne	Attendant Archeologist(s):	Attendant Soil Scientist(s):		

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			5Y4/2 (olive gray)	0-10 cm. Silt loam, loose, dry, abundant fine roots. Moderate organic matter.	A Horizon	Topsoil		0-10	
10			5Y4/4 (olive)	10-27 cm. Sandy loam. Abundant concretions. Concretionary layer discontinuous along bank. Concretions to 4 cm diam., CaCO3 rich, surrounding matrix loose.	Bk1	Levee aeolian		10-27	
20									
30			5Y5/2 (olive gray) to 5Y7/1 (light gray)	27-87 cm. Silt loam, mottled, concretions common. Concretions 3-8 mm diam. Concretions react to HCl. Abundant small burrows 2-5 mm diam. Clay does not react to HCl.	Bkg2	Floodplain backswamp, marsh distal levee		27-87	
40									Bioturbated
50				Subtlle, irregular contact with unit below.					

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)

Project:	Location:	Exposure ID:	Date:	Site Coordinator:	Log recorder:	Sheet 2
Ancient Remains	Kennewick, WA	CPP268	12/14/97	L.D. Wakeley	Warne	of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60			5Y5/2 to 5Y7/1 con'd			Floodplain backswamp, marsh distal levee				Extensively bioturbated
70					Bkg2					
80				Gradual transition from upper material to material below from 87 to 106						
90			2.5Y4/3 (grayish to olive brown),	87-116 cm. Silty Clay loam, rather soft, but forms small bench in lower 90 cm of profile.	Bkg3	Floodplain backswamp, marsh			87-116	Bioturbated
100				Slight concentration of concretions at ~106 cm. Reacts with HCl.						
110			2.5Y4/3 (grayish to olive brown),	116-177 cm. Silty Clay layer, generally homogeneous but faintly mottled. Slightly harder than above, no concretions seen.	Bt				116-177	

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project:	Location:	Exposure ID:	Date:	Site Coordinator:	Log recorder:	Sheet 3
	Ancient Remains	Kennewick, WA	CPP268	12/14/97	L.D. Wakeley	Warne	of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			2.5Y4/3 (grayish to olive brown) con'd	as above	Bt					
130						Floodplain backswamp, marsh				
140										Bioturbated
150										
160										
170				Base of profile 177 cm.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP296	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 346.7 ft	Exposure Coordinates: 2336045E 328588N ft NAD27	Sheet 1 of 3 Sheets
Person(s) Preparing Field Excavation Log: A.G. Warne & L.D.Wakeley	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes			Methods used to Prepare Exposure: Hand Trowel		Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne			Attendant Archeologist(s):			Attendant Soil Scientist(s):	

Strat. Pos. (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank			10YR3/3 (dark brown)	0-8 cm. sandy loam, loose, abundant fine and medium roots. Gradational contact below.	A Horizon	Topsoil		0-8	Animal burrows start.
10			5Y4/4 (olive)	8-17 cm. Fine sandy loam, loose, medium roots common. Flecks may be volcanic glass.	Bk1	Levee aeolian distal, alluvial fan		8-17	
20			5Y5/4 or3 (olive)	17-32 cm. Loam. Animal burrows 3-4 cm. high by 8-10 cm wide (oblique to face). Medium roots common. Faintly mottled.	Bkg2			17-32	Animal burrows frequent.
30			2.5Y5/3 (grayish to olive brown)	32-55 cm. Silt loam. Fine abundant pores 2-5 mm. Faintly mottled. Not sticky, dense. No concretions. Harder than layer below.				32-55	No burrows.
40					Bkg3	Floodplain backswamp, marsh, distal levee			Forms horizontal fissile structure visible on weathered surface. Bioturbated
50			2.5Y5/4 (light ovive brown)	55-90 cm. Faintly mottled silt loam. Concretions common and calcareous. Concretions 8 cm X 3 cm and irregular. Large concretions are lag type on strand.	Bkg4			55-90	Concretions abundant. Collected during screening.

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP296	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 2 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60			2.5Y5/4 con'd	as above						Concretions abundant on strand as lag deposit.
70					Bkg4	Floodplain backswamp				Bioturbated
80										
90			5Y4/4 (olive)	90-122 cm. Silty clay loam, dense, distinctly mottled. Fewer concretions, lighter mottling in horizontal streaks. Concretions only 5 mm.	Bk5				90-122	Unit is preferentially removed by erosion and undercutting.
100										Bioturbated
110										

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP296	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 3 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			5Y4/4 (olive)	as above						
130			5Y4/3 (olive)	122-143 cm. Silty clay loam, mottling somewhat distinct. Concretions 5 mm and larger. forms low ledge.	Bt6				122-143	Slight ledge former. Calcareous deposit on exposed surface where not cleared.
140			5Y4/3 (olive)	143-164 cn, Silty clay loam, some silt. Homogeneous, soft, easily eroded. No concretions.					143-164	
150										Extensively bioturbated
160				Base of profile 164 cm.	—					
170										

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG

GEOARCHEOLOGICAL BANK PROFILE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 12/14/97	Exposure ID: CPP334	Type of Exposure: (bank, trench, etc).	Elevation at Top of Exposure: 347.1 ft	Exposure Coordinates: 2335930E 328634N ft NAD27	Sheet 1 of 3 Sheets
Person(s) Preparing Field Excavation Log: A.G. Warne & L.D.Wakeley	Persons and (or) Organization(s) Conducting Excavation: WES & Consolidated. Tribes	Methods used to Prepare Exposure: Hand Trowel	Width of Exposure: 50 cm	Height of Exposure: 124 cm	Quality of Exposure: Good			
Site Coordinator: L.D. Wakeley	Attendant Geologist(s): J.B. Dunbar, W.L. Murphy, L.D. Wakeley, A.G. Warne	Attendant Archeologist(s):	Attendant Soil Scientist(s):					

Strat. Pos. (cm)	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Sample/ Photo #	Remarks
Top of Bank	5Y3/2 (dark olive gray)	0-13 cm. sandy loam,. Abundant fine roots. Organic	A Horizon	Topsoil		0-13	A horizon
10	2/5Y4/2 (dark grayish brown)	13-18 cm. Sandy loam. Clasts common, ~ 5 mm. Fine roots common.	Bk1			13-18	Clasts may be rworked tephra
20	2.5Y4/3 (grayish to olive brown)	18-22 cm. Sandy loam with tephra clasts, matrix supported, rounded, 5-10 mm.				18-22	
	10YR8/2 (white)	22-39 cm. Tephra, sandy loam texture. Dark flecks. Fine roots common. Probably reworked	Bkg2	Distal alluvial fan		22-39	Volcanic ash (Mazama airfall), reworked and thickened, bioturbated(?)
30							Ash and indurated layer break into boulders on beach.
						Oriented sample at 36-39 cm.	
40	2.5Y6/2 (light brown gray)	Indurated layer at base. Bottom of tephra sharp. 39-42 cm. Brittle sandy loam and indurated. Weak reaction to HCl. Bottom contact gradational.	Bkg3			39-42	12/18 - Maybe discontinuity ~4 cm below tephra. May be poorly developed buried soil. 2-5 mm pores.
50	2.5Y5/2 (grayish brown) and mottled to 2.5Y6/2	42-90 cm. Silt loam (ML). Many concretions, 20 X 15 mm. Strong reaction to HCl. Fines downward. Fine mottles, 5-10 mm. Intensely bioturbated. Concretions continue down with moderate to strong reaction to HCl.	Bkg4	Floodplain backswamp, distal levee		39-42	Erodes easily. Layer preferentially removed to undercut bank. Bioturbated.

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Exposure ID: CPP334	Date: 12/14/97	Site Coordinator: L.D. Wakeley	Log recorder: Warne, Wakeley	Sheet 2 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60–70			2.5Y5/2 (grayish brown) mottled to 2.5Y6/2	as above						
70–80					Bkg4	Floodplain backswamp, marsh distal levee				Bioturbated
80–90										
90–100			2.5Y5/3 (grayish to light olive brown)	90-145 cm. Silty clay loam, Soft, minimal mottling. Few concretions. Fine holes and pores.	Bk5	Floodplain backswamp, marsh			90-145	In fresh profile, no obvious break between layers at this contact. Bad light, color call difficult. More resistant to erosion where bank undercut by removal of layer above. Forms slight terrace
100–110										Bioturbated
110–										

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEORCHEOLOGICAL BANK PROFILE LOG (CONTINUATION SHEET)	Project:	Location:	Exposure ID:	Date:	Site Coordinator:	Log recorder:	Sheet 3
	Ancient Remains	Kennewick, WA	CPP334	12/14/97	L.D. Wakeley	Warne, Wakeley	of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			2.5Y5/3 (grayish to light olive brown)	as above						
130				Clay continues, less mottled.					122-143	
140				Base of profile 145 cm.	—	—			143-164	
150										
160										
170										

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL SITE CORE LOG

Project: Ancient Remains	Location: Kennewick, WA	Date: 1/14/98	Core ID: CPC-044	Core Coordinates: 2336845 E 328377 N ft NAD'27	Elevation at Top of Core: 339.5 ft	Total Depth of Core: 232cm	Sheet 1 of 4 Sheets
Person Recording Drilling Log: Warne/Wakeley	Drilling Agency: WES	Name of Driller: Dunbar	Size and Type of Drilling/Coring Device: Vibracore 3"	Depth to Water Table:	Setting of Drilling Site: Beach		
Site Coordinator During Drilling: Wakeley	Attendant Geologist(s): Warne, Wakeley, Dunbar, Murphy	Attendant Archeologist(s): Fred Briuer	Attendant Soil Scientist(s):	Quality of Core: Excellent			

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
GL			2.5Y4/3 (grayish to olive brown)	0-10 cm. Fine silt loam. Small concretions.					0-10 cm C content, grain size	Reworked concretions likely from elsewhere. No reaction to acid. X-ray indicates about 50 nodules (1.5 cm),
10			10YR 3/3 (dark brown)	10-59 cm. Silt loam to silty clay loam. Remarkably uniform, very soft. Water retention indicated by surface sheen.					10-20 cm.	Clay forms string
20									20-30 cm.	X-ray indicates extensive bioturba-tion.
30									30-40 cm.	No reaction to HCl
40									40-50 cm.	
50									50-59 cm.	
			10YR 3/3 (dark brown)	59-67 cm. Fine sandy loam. Clay drags at core boundaries.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-044	Date: 1/14/98	Site Coordinator: Wakeley	Log recorder: Warne/Wakeley	Sheet 2 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60			10YR3/3 as above	Fine sandy loam as above.					59-67 cm.	
70			10YR 3/3 (dark brown)	67-76 cm. Silt loam.					67-76 cm.	X-ray indicates extensive bioturbation. Boundaries at 67 and 76 not distinguishable on X-rays.
80			10YR 3/3 (dark brown)	76-110 cm. Fine sandy loam grading back to silt loam downward.					76-90 cm.	No reaction to HCl.
90									90-100 cm.	
100									100-110 cm	
110			10YR 3/4 (dark yellowish brown)	110-151 cm. Sharp contact. Fine sandy loam, very uniform.					110-120 cm	Faint lamination in X-ray.

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-044	Date: 1/14/98	Site Coordinator: Wakeley	Log recorder: Warne/Wakeley	Sheet 3 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			10YR3/4 as above	Fine sandy loam as above.					120-130 cm.	Mostly homogeneous in X-ray.
130									130-140 cm	
140									140-151 cm.	No reaction to HCl.
150			10YR 3/3 (dark brown)	151-169 cm. Silt loam.					151-160 cm	
160									160-169 cm	X-ray shows weak laminae from 166-169. X-ray shows fine ripple laminations from 169-172.
170			10YR 3/1 (very dark gray)	169-172 cm. sand loam.					169-172 cm	
			10YR 3/4 (dark yellowish brown)	172-184 cm. Silt loam.					172-184 cm	Weakly cross-laminated from 171-172.

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-044	Date: 1/14/98	Site Coordinator: Wakeley	Log recorder: Warne/Wakeley	Sheet 4 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
180			10YR3/4 as above	Silt loam as above.					180-184 cm.	
									184-190 cm.	
190									190-199 cm	X-ray shows faint lamination from 188-191
										No reaction to HCl.
200			10YR 3/1 (very dark gray)	184-199 cm. fine sand loam. Grades to silt loam.					199-201 cm.	
			10YR 3/3 (dark brown)	199-201 cm. Sand with heavy minerals. Sharp contact at base.					201-208 cm	No discernible sed structure in X-ray for 199-201.
210			10YR 3/1 (very dark gray)	208-213 cm. Sand with heavy minerals at base.					208-213 cm	Weakly laminated from 207 to 232.
			10YR 3/3 (dark brown)	213-217 cm. Silt loam.					213-217 cm	
220			10YR 3/1 (very dark gray)	217-222 cm. Sand with heavy minerals.					217-222 cm.	
			10YR 3/4 (dark yellowish brown)	222-232 cm. Fine sandy loam.					222-232 cm	
230				232 cm. Base of core.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL SITE CORE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 1/14/98	Core ID: CPC-054	Core Coordinates: 2336799 E 328388 N ft NAD'27	Elevation at Top of Core: 338.9 ft	Total Depth of Core: 206cm	Sheet 1 of 4 Sheets
Person Recording Drilling Log: Warne/Wakeley	Drilling Agency: WES	Name of Driller: Dunbar	Size and Type of Drilling/Coring Device: Vibracore 3"	Depth to Water Table:	Setting of Drilling Site: Terrace above beach. 3.2 m lakeward of bank.			
Site Coordinator During Drilling: Wakeley	Attendant Geologist(s): Warne, Wakeley, Dunbar, Murphy	Attendant Archeologist(s): Fred Briuer	Attendant Soil Scientist(s):	Quality of Core: Excellent				

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
GL			5Y4/3 (olive)	0-15 cm. Fine sandy loam.					0-10 cm	X-ray shows laminations. 0-15 cm are modern to historic material from surf zone.
										No reaction to HCl
10									10-15 cm.	Nodule apparent on X-ray.
			10YR 4/2 (dark grayish brown)	Sharp conctact, with concretions at base, 1-cm diam.						Appears homogeneous.
				15-59 cm. Silt loam. Visibly micaceous.					15-20 cm.	
20									20-30 cm.	Very faintly mottled. X-rays indicate extensive bioturbation.
30									30-40 cm.	No reaction to HCl
40									40-50 cm.	Faintly mottled in X-ray.
50									50-59 cm.	
			10YR 3/4 (dark yellowish brown)	59-104 cm. Angled contact from 59 to 63 cm depth. Fine sandy loam, more micaceous downward.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-054	Date: 1/14/98	Site Coordinator: Wakeley	Log recorder: Warne/Wakeley	Sheet 2 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60			10YR3/4 as above	Fine sandy loam as above.					59-70 cm.	Contact with unit above is irregular.
70									70-80 cm.	
80				Fines increase with depth. Grades to silt loam.					90-100 cm.	No reaction to HCl.
90									100-104 cm	
100			10YR 3/2 (very dark grayish brown)	104-13 cm. Sand, fine to medium grained.					104-110 cm	Cross-bedded laminations apparent on X-ray.
110				Gradational with depth to silt loam.					110-120 cm	No reaction to HCl.

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-054	Date: 1/14/98	Site Coordinator: Wakeley	Log recorder: Warne/Wakeley	Sheet 3 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			10YR3/2 as above	Sand, grading downward to silt loam, as above.					120-130 cm.	
130									130-134 cm 134-140 cm	
			10YR 3/3 (dark brown)	135-158 cm. Silt loam, homogeneous.						
140									140-150 cm.	No reaction to HCl. Faintly and extensively mottled on X-ray.
150									150-158 cm	
160			10YR 3/3 (dark brown)	158-175 cm. Sharp contact. Fine sand or sandy loam. Micaceous, homogeneous.					158-167cm.	No reaction to HCl.
									167-175 cm.	Laminations apparent on X-ray.
170										Homogeneous on X-ray.
			10YR 3/3 (dark brown)	175-184 cm. Sharp contact. Silt loam.					175-184 cm.	No reaction to HCl.

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-054	Date: 1/14/98	Site Coordinator: Wakeley	Log recorder: Warne/Wakeley	Sheet 4 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
180			10YR3/3 as above	Silt loam as above.						
				184-206 cm. Fine sand loam to sand loam, gradational.					184-194 cm	No reaction to HCl.
190				sandier at depth						
									194-206 cm	Faintly mottled on X-ray.
200										
				204 cm, heavy mineral layer.						
				Base of core 206 cm.						
210										
220										
230										

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL SITE CORE LOG

GEOARCHEOLOGICAL SITE CORE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 1/27/98	Core ID: CPC-059.5	Core Coordinates: 2336775 E 328367 N ft NAD'27	Elevation at Top of Core: 343 ft	Total Depth of Core: 237 cm	Sheet 1 of 4 Sheets
Person Recording Drilling Log: Murphy	Drilling Agency: WES	Name of Driller: Dunbar	Size and Type of Drilling/Coring Device: Vibracore 3"		Depth to Water Table:	Setting of Drilling Site: Terrace above beach.		
Site Coordinator During Drilling: Wakeley	Attendant Geologist(s): Warne, Dunbar, Murphy		Attendant Archeologist(s): Fred Briuer			Attendant Soil Scientist(s):		Quality of Core: Excellent

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
GL			N.A.	0-25 cm. Fine sandy loam with abundant nodules.					0-10 cm	
10									10-20 cm.	
20									20-25 cm.	
				25-66 cm. Fine sandy loam with no nodules.					25-30 cm.	
30									30-40 cm.	
40									40-50 cm.	
50									50-60 cm.	

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)

Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-059.5	Date: 1/27/98	Site Coordinator: Wakeley	Log recorder: Murphy	Sheet 2 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60									60-66 cm.	
			N.A.	66-98 cm. Silt loam, with clay.					66-70 cm.	
70									70-80 cm.	
80									80-90 cm.	
90									90-98 cm.	
100				98-118 cm. Silt loam and fine sand loam, less clay, with mica.					98-110	
110									110-119 cm.	
				118-138 cm. Silt loam, less mica.						X-ray sample split at 118 cm.

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-059.5	Date: 1/27/98	Site Coordinator: Wakeley	Log recorder: Warne/Murphy	Sheet 3 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120			N.A.						119-130 cm	
				127 cm. Denser, harder.						
130									130-138 cm	
140				138-167 cm. Silt loam, less dense than above.					138-150 cm	
150									150-160 cm	
160									160-170 cm	
				167-177 cm. Fine sandy loam.						
170									170-177 cm	
				177-229 cm. Silt loam, dense, drier.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-059.5	Date: 1/27/98	Site Coordinator: Wakeley	Log recorder: Warne/Murphy	Sheet 4 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
180			N.A.						177-190 cm.	
190				At 196 cm, becomes nore clay rich.					190-200 cm	
200									200-210 cm	
210									210-220 cm.	
220				gradational with depth					220-230 cm	
230				229-237 cm. Silt loam, clayey.					230-237 cm	
				237 cm. Base of core.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL SITE CORE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 1/20/98	Core ID: CPC-200	Core Coordinates: 2336322 E 328441 N NAD'27	Elevation at Top of Core: 341 ft	Total Depth of Core: 228 cm	Sheet 1 of 4 Sheets
Person Recording Drilling Log: Warne/Murphy	Drilling Agency: WES	Name of Driller: Dunbar	Size and Type of Drilling/Coring Device: Vibracore 3"		Depth to Water Table:	Setting of Drilling Site: base of river bank		
Site Coordinator During Drilling: Wakeley	Attendant Geologist(s): Warne, Dunbar, Murphy		Attendant Archeologist(s): Fred Briuer			Attendant Soil Scientist(s):		Quality of Core: Excellent

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
GL			2.5Y4/3	0-15 cm. Reworked modern, sandy loam, grades downward to silt loam starting at 9 cm.					0-10 cm	
10									10-15 cm.	
			10YR4/3	15-130 cm. silt loam, homogeneous (no layering evident).					15-20 cm.	Fairly clay rich, very slick to feel
20									20-30 cm.	
30									30-40 cm.	
40									40-50 cm.	
50									50-60 cm.	

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-200	Date: 1/20/98	Site Coordinator: Wakeley	Log recorder: Warne/Murphy	Sheet 2 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60			10YR4/3	Silt loam as above					60-70 cm.	
70									70-80 cm.	
80									80-90 cm.	
90									90-100 cm.	
100									100-110 cm	
110									110-120 cm	X-ray sample split at 118 cm.

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-200	Date: 1/20/98	Site Coordinator: Wakeley	Log recorder: Warne/Murphy	Sheet 3 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120									120-130 cm.	
130			10YR4/2	130-228 cm. Gradational contact with above Silt loam, darker than above. Very homogeneous. Becomes coarser with depth.					130-140 cm	
140									140-150 cm	
150									150-160 cm.	
160									160-170 cm	
170									170-180 cm	

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-200	Date: 1/20/98	Site Coordinator: Wakeley	Log recorder: Warne/Murphy	Sheet 4 of 4 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
180				As above					180-190 cm.	
190									190-200 cm	
200									200-210 cm	
210									210-220 cm.	
220									220-228 cm	
230				base of core 228 cm.						

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL SITE CORE LOG

GEOARCHEOLOGICAL SITE CORE LOG	Project: Ancient Remains	Location: Kennewick, WA	Date: 1/20/98	Core ID: CPC-268	Core Coordinates: 2336130 E 328552 N NAD'27	Elevation at Top of Core: 340.1 ft	Total Depth of Core: 180 cm	Sheet 1 of 3 Sheets
Person Recording Drilling Log: Warne/Murphy	Drilling Agency: WES	Name of Driller: Dunbar	Size and Type of Drilling/Coring Device: Vibracore 3"		Depth to Water Table:	Setting of Drilling Site: base of river bank		
Site Coordinator During Drilling: Wakeley	Attendant Geologist(s): Warne, Dunbar, Murphy		Attendant Archeologist(s): Fred Briuer			Attendant Soil Scientist(s):		Quality of Core: Excellent

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
GL			10YR4/1	0-9 cm. Silt loam and fine sandy loam. Abundant calcareous nodules to 3 cm diam. (50% concretions).					0-9 cm	Coarse sand at base (0-9 cm). Beach lag.
10			10YR4/2	9-28 cm. Silt loam. Animal burrows 1-2 mm diam.					9-20 cm.	
20									20-28 cm.	
30			10YR4/3	28-110 cm. Silt loam, clayey. Appears mottled. Bioturbated.					28-40 cm.	
40									40-50 cm.	
50									50-60 cm.	

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-268	Date: 1/20/98	Site Coordinator: Wakeley	Log recorder: Warne/Murphy	Sheet 2 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
60									60-70 cm.	
70				At about 75 cm, soil is grittier, with less clay.					70-80 cm.	
80									80-90 cm.	
90									90-100 cm.	
100									100-110 cm	
110				110-180 cm. Silt loam.					110-120 cm	

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

GEOARCHEOLOGICAL CORE LOG (CONTINUATION SHEET)	Project: Ancient Remains	Location: Kennewick, WA	Core ID: CPC-268	Date: 1/20/98	Site Coordinator: Wakeley	Log recorder: Warne/Murphy	Sheet 3 of 3 Sheets

Depth (cm)	Graphic Log: Lithology	Graphic Log: Color	Munsell Color	Description of Soil/Sediment	Soil Horizon	Env. of Deposition	Cultural Material[1]	Cultural Feature	Sample/ Photo #	Remarks
120									120-130 cm.	
130				130-180 cm. Pronounced vugginess indicating burrowing, up to 1 cm diam.					130-140 cm	
140									140-150 cm	
150									150-160 cm.	
160									160-170 cm	
170				Base of core 180 cm.					170-180 cm	

[1] Cultural Material : PC - Prehistoric Ceramic; L - Lithic; FCR - Fire Cracked Rock; B - Bone; C - Charcoal; HC - Historic Ceramic; G - Glass; OH - Other Historic

Examples of Coulter counter grain size analysis of samples from Kennewick site stratigraphic layers V (CPP-044) and VI (CPC-044), respectively.

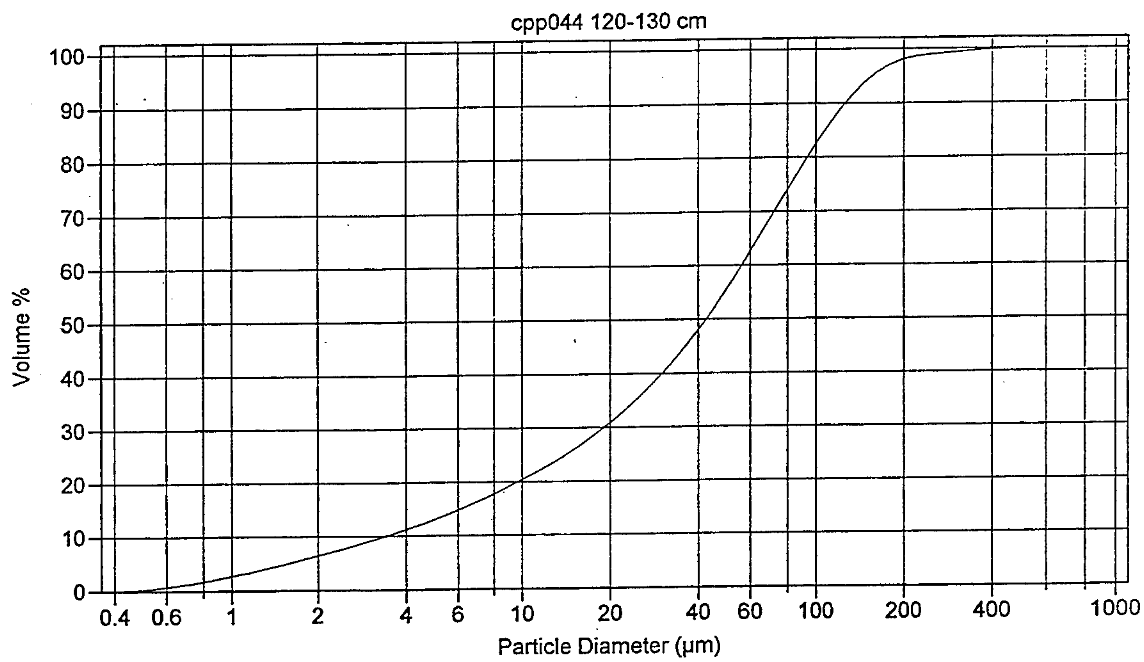
COULTER®

LS Particle Size Analyzer

Page 1
19 Mar 1998

KENNEWICK WA Grain Size Analysis

File name:	cpp044.$01	Group ID:	cpp044
Sample ID:	cpp044 120-130 cm		
Operator:	vaughan	Run number:	17
Comments:	CaCO3 removed, organics removed, calgon added mar 3 1998		
Optical model:	Fraunhofer		
LS 100Q	Fluid Module		
Start time:	12:36 2 Mar 1998	Run length:	60 Seconds
Pump speed:	67		
Obscuration:	9%		
Fluid:	Water		
Software:	2.09	Firmware:	2.02 2.02



KENNEWICK WA Grain Size Analysis

Volume Statistics (Arithmetic) cpp044.$01

Calculations from 0.375 µm to 948 µm

Volume	100.0%		
Mean:	56.40 µm	S.D.:	55.5 µm
Median:	42.47 µm	C.V.:	98.4%
D(3,2):	8.502 µm	Skewness:	2.02 Right skewed
Mode:	72.95 µm	Kurtosis:	7.09 Leptokurtic

% <	10	25	50	75	90
Size µm	3.421	14.12	42.47	82.20	126.7

cpp044.$01

Size µm	ASTM	Cum. < Volume %	Diff. Volume %
0	999	0	46.54
38	400	46.54	5.41
45	325	51.95	5.82
53	270	57.77	6.69
63	230	64.46	6.95
75	200	71.41	7.11
90	170	78.52	5.90
106	140	84.42	5.23
125	120	89.66	4.54
150	100	94.20	2.94
180	80	97.13	1.30
212	70	98.43	0.527
250	60	98.96	0.358
300	50	99.32	0.339
355	45	99.66	0.265
425	40	99.92	0.074
500	35	100.00	0.005
600	30	100.00	0
710	25	100.00	0
850	20	100.00	0
		100.00	

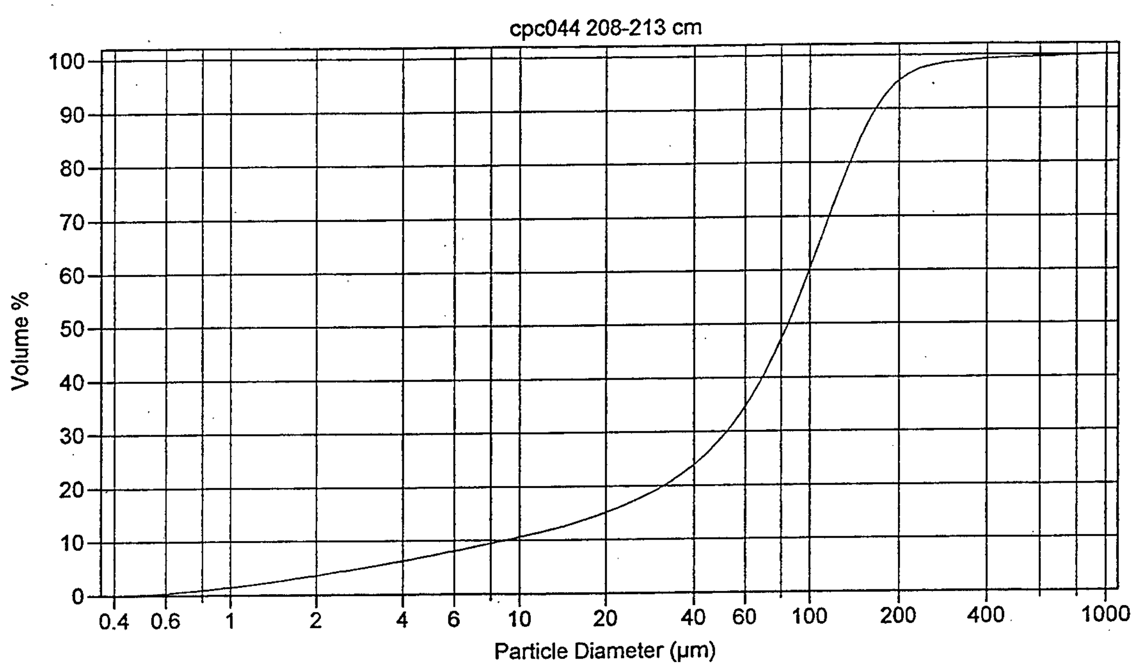
COULTER®

LS Particle Size Analyzer

19 Mar 1998

KENNEWICK WA Grain Size Analysis

File name:	cpc044.$88	Group ID:	cpc044
Sample ID:	cpc044 208-213 cm		
Operator:	vaughan	Run number:	1
Comments:	CaCO3 removed, organics removed, calgon added mar 3 1998		
Optical model:	Fraunhofer		
LS 100Q	Fluid Module		
Start time:	11:18 2 Mar 1998	Run length:	60 Seconds
Pump speed:	67		
Obscuration:	9%		
Fluid:	Water		
Software:	2.09	Firmware:	2.02 2.02



KENNEWICK WA Grain Size Analysis

Volume Statistics (Arithmetic) cpc044.$88

Calculations from 0.375 µm to 948 µm

Volume	100.0%		
Mean:	91.89 µm	S.D.:	77.2 µm
Median:	84.52 µm	C.V.:	84%
D(3,2):	14.88 µm	Skewness:	3.5 Right skewed
Mode:	116.3 µm	Kurtosis:	26.7 Leptokurtic

% <	10	25	50	75	90
Size µm	8.927	42.34	84.52	125.6	167.0

cpc044.$88

Size µm	ASTM	Cum. < Volume %	Diff. Volume %
0	999	0	22.92
38	400	22.92	3.44
45	325	26.36	4.22
53	270	30.58	5.76
63	230	36.34	7.49
75	200	43.83	9.85
90	170	53.68	10.30
106	140	63.97	10.79
125	120	74.76	10.53
150	100	85.30	7.38
180	80	92.67	3.58
212	70	96.26	1.57
250	60	97.83	0.780
300	50	98.61	0.428
355	45	99.04	0.306
425	40	99.35	0.175
500	35	99.52	0.135
600	30	99.66	0.099
710	25	99.75	0.125
850	20	99.88	0.120
		100.00	

Appendix E

Pedologic and Geomorphic Assessment
of the Kennewick Site,
Contributed by Dr. Douglas A. Wysocki,
Research Soil Scientist, NRCS,
Lincoln, Nebraska

Pedologic and Geomorphic Assessment of the Kennewick Site

Dr. Douglas A. Wysocki
Research Soil Scientist
NRCS, Lincoln, NE

Purpose:

This report summarizes the soil, stratigraphic, and geomorphic relationships at the Kennewick Site. Field observations were made 17-19 December 1997.

Location:

The Kennewick site is on the southerly side of the Columbia River (Lake Wallula) in Columbia Park in the city of Kennewick, WA. The site is in the NW 1/4 of section 34 T9N, R29E with an approximate latitude of N 46° 13' 02" and longitude of W19° 10' 14". The site is on the Kennewick 7.5 minute Quadrangle.

Geomorphic Setting:

The Kennewick site is a stream terrace directly adjacent to Lake Wallula. The present surface elevation of the terrace is no more than two meters above the pool elevation of Lake Wallula. The area of primary importance is a terrace remnant about 500 meters long by 75 meters wide that is between Lake Wallula and Columbia Avenue. The northerly portion of the terrace remnant is onlapped by an alluvial fan. A steep, convex slope to the south of Columbia Avenue separates the terrace from an older, higher terrace that is underlain by Spokane Flood Gravels.

Soils and Stratigraphy:

Three detailed soil descriptions were made following the procedures of the Soil Survey Staff (1993). Two soil descriptions are from the bank exposure at the edge of the terrace where it adjoins the water. Field observations and notes were made at other locations along the bank, but time was not available for detailed descriptions. The third soil description is from a cut bank exposure on the south side of Columbia Avenue on a hillslope above the terrace.

Soil Descriptions:

Bank Exposure Profile at CPP-005

A 0 to 10 cm, very dark gray 10YR 3/1, loam, weak fine granular structure, very friable, many fine and very fine roots, slightly effervescent, clear smooth boundary.

BA 10 to 28 cm, dark grayish brown 2.5Y 4/2, loam, weak, medium subangular blocky structure, very friable, many fine and medium roots, strongly effervescent clear smooth boundary.

Bw 28 to 48 cm, grayish brown 2.5 Y 5/2, silt loam, weak medium subangular blocky structure, friable, many fine and medium roots, strongly effervescent, gradual smooth boundary.

Bk1 48 to 63 cm, grayish brown 2.5Y 5/2, silt loam, weak medium subangular blocky structure, friable, many fine and medium roots, common medium and coarse irregular and dendritic carbonate nodules in root channels and pores, strongly effervescent, gradual smooth boundary.

Bk2 63 to 81 cm, grayish brown 2.5Y 5/2, loam, weak medium subangular blocky structure, friable, many fine and medium roots, few fine irregular carbonate nodules, slightly effervescent, clear smooth boundary.

2BA1b 81 to 105 cm, dark grayish brown 2.5Y 4/2 silt loam with dark yellowish brown 10YR 4/3 ped exteriors, weak medium subangular blocky structure, friable, many medium roots, very slightly effervescent, clear smooth boundary.

2BA2b 105 to 120+ cm, dark grayish brown 2.5Y 4/2 silt loam with dark yellowish brown 10YR 4/3 ped exteriors, common medium faint grayish brown 2.5 Y 5/1 iron depletions as pore linings, common medium prominent strong brown 10YR 5/8 iron concentrations around pores or as pore linings, weak medium subangular blocky structure, friable, many medium roots, very slightly effervescent.

Bank Exposure Profile at CPP-054

A 0 to 8 cm, very dark grayish brown 10YR 3/2, very fine sandy loam, weak fine granular structure, very friable, many fine and very fine roots, slightly effervescent, clear smooth boundary.

Bw 8 to 70 cm, olive brown 2.5Y 4/3, very fine sandy loam, weak, fine and medium subangular blocky structure, very friable, many fine and medium roots, strongly effervescent clear smooth boundary (ash at base of this horizon on adjacent bank, but not in this profile).

2BAkb 70 to 135 cm, dark grayish brown 2.5Y 4/2, silt loam, moderate medium subangular blocky structure, friable, many fine and medium roots, faint patchy clay films occur in a few pores, common medium irregular and dendritic carbonate nodules in pores and root channels, strongly effervescent, gradual smooth boundary.

2BA1b 135 to 150 cm, dark grayish brown 2.5Y 4/2, silt loam, weak medium subangular blocky structure, friable, many fine and medium roots, strongly effervescent, gradual smooth boundary.

2BA2b 150 to 174 cm, dark grayish brown 2.5Y 4/2, silt loam, weak medium subangular blocky structure, friable, many fine and medium roots, slightly effervescent, clear smooth boundary.

2Bwb 174 to 190 cm, dark grayish brown 2.5Y 4/2 silt loam, weak medium subangular blocky structure, friable, many medium roots, non-effervescent.

Road Cut Exposure on Gravel Bar above Terrace

A 0 to 20 cm, very dark grayish brown 10YR 3/2, loamy very fine sand with less than 5% gravel, weak fine granular structure, very friable, many fine and very fine roots, non-effervescent, clear smooth boundary.

Bkm 20 to 45 cm, dark grayish brown 2.5Y 4/2, very gravelly sand, gravels are completely cemented by carbonate (stage III), massive, very firm, violently effervescent, gradual smooth boundary.

Bk 45 to 60+ cm, dark grayish brown 2.5Y 4/2, very cobbly sand, gravels and cobbles coated with carbonate, but carbonate does not form continuous cement, massive, firm, violently effervescent.

Stratigraphic Interpretation:

The strata and soil horizons present at the site can be used to interpret the geomorphic and stratigraphic history of the site. Two distinct lithostratigraphic units are evident within the thickness of bank that is exposed. The upper or surface unit is a sandy deposit about 70 to 80 cm thick. The basal portion of this unit contains volcanic ash. The most likely source of the ash is Mount Mazama. The ash does not form a continuous strata throughout the unit. The ash appears

to be reworked by slope wash, and does not represent primary air fall. If the ash is from a Mazama source, the base of the surface unit has an age of about 6,800 yr B.P.

Both fluvial and eolian processes contributed to the deposition of the surface unit. The soil descriptions show a lateral variation in particle size across the surface unit. At CPP 054 the texture in the upper unit is a very fine sandy loam. The same unit at CPP 05 is a loam or silt loam. The minor topographic lows are slightly fine textured than the topographic highs. This suggests a fluvial process such as overbank deposition or slope wash or a combination of these. Small gravels up to 1 cm across can be found occasionally within the surface unit. This is additional evidence for a fluvial origin. The older and lower stratigraphic unit exposed in the stream bank is a silt loam with no geologic structure. The medium texture and lack of structure suggest a backswamp or slack water origin for this unit.

The surface soil on the hillslope above the terrace is a loamy fine sand with less than 5% gravel by field estimate. The deeper horizons have a gravel and cobble content of 60% or more by field estimate. The sandy surface is a deposit of eolian sand, which will mantle all pre-existing surfaces. Eolian sand must also occur on the terrace, if the terrace is older than the sand. This sand would be a component of the upper stratigraphic unit on the terrace.

Soils:

The soils on the terrace have composite profiles. Soil horizons had developed in the lower stratigraphic unit prior to deposition of the upper unit. The soil horizons in the lower unit have a uniform degree of development within the depth exposed. The horizons display some characteristics of both B horizons (blocky structure, carbonate nodules, faint clay films) and A horizons (organic stained peds). The soil formed upward on an aggrading surface. The buried profile lacks a distinct A horizon, but the soil structural units (peds) are laterally compressed by the weight of the upper stratigraphic unit. Formation of the soil structure predates the deposition of the upper unit. The absence of a buried A horizon suggests that the lower soil was truncated before or at the time the upper unit was deposited.

Carbonate nodules in the B horizons of soils on the terrace equate to a stage II carbonate formation (Gile, Peterson, and Grossman 1966). In New Mexico Gile, Peterson, and Grossman (1966) set a minimum age of 5,000 years for stage II carbonate development. The exact precipitation and carbonate inputs at the Kennewick site differ from the New Mexico location. Five thousand years, however, is a reasonable estimate for the soil age based on the geomorphic setting and present atmospheric inputs. Sediment in the lower stratigraphic unit becomes less reactive or non-reactive to acid with increasing depth. Source for

the carbonates must come from eolian, aerosol, or precipitation sources and or the sediment in the upper stratigraphic unit.

The gravelly soil on the adjacent hillslope contains a carbonate cemented B horizon. This equates to stage III carbonate development (Gile, Peterson, and Grossman 1966). A surface age of late Pleistocene or older was required to get stage III development in New Mexico. The degree of carbonate development in the soil on the hillslope suggests that the age of this surface is significantly older than the terrace surface or the alluvial fan surface to the west.

Summary:

The soil and stratigraphic sequence at the Kennewick site suggests a multistage development for the terrace. The lower stratigraphic unit (at least that portion that is exposed in the bank) is an overbank or slackwater deposit in which some soil development took place. The soil was truncated and the upper stratigraphic unit deposited. Soil formation began again producing a composite soil profile across both stratigraphic units.

Recommendation:

The age of the carbon in the carbonate nodules can be measured by C14 analysis. This analysis would provide an independent means of estimating the age the soils and sediments. Recent root activity and transfer of soluble organic carbon will have less influence on the age of carbonate nodules than on bulk carbon in soils.

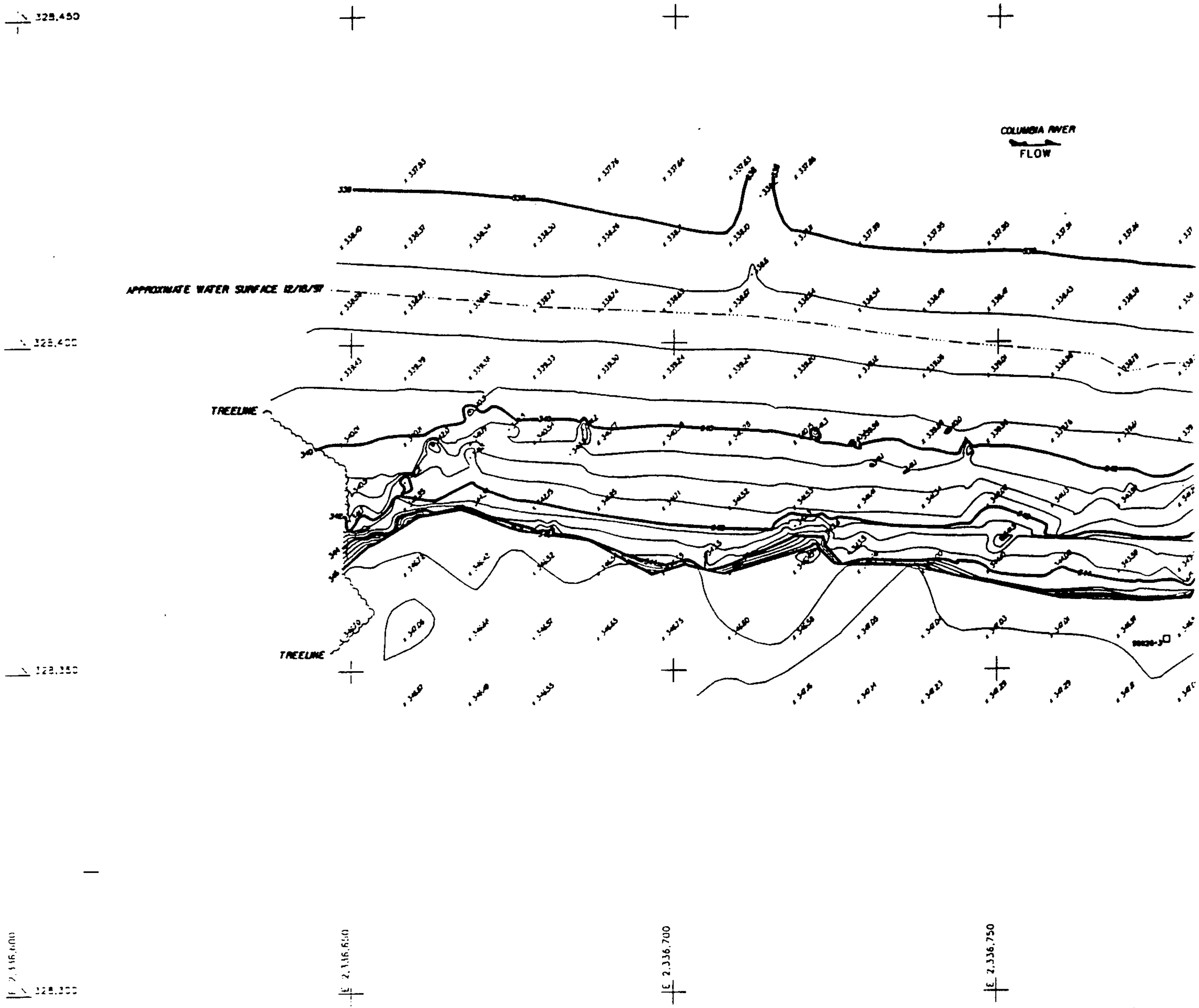
Literature Cited

Gile, L. H., Peterson, F. F., and Grossman, R. B. (1966). Morphological and genetic sequences of carbonate accumulation in desert soils. Soils Science. 101: 347-360.

Soil Survey Staff. (1993). The Soil Survey Manual. USDA-Soil Conservation Service, Agricultural Handbook 18, U.S. Gov Print. Office, Washington, D.C. 503pp.

Appendix F

Site Maps from CENWW Site Survey,
December 1997



CONTROL DATA

Reference	North	East	Elevation	Description
100	331560.52	2336168.22	360.14	PK &W
101	334446.72	2334462.08		PASCO RADIO STA KALE CEN
102	328677.17	2335106.84		H & T
103	330004.36	2331704.91	348.20	CR-9-RB
98026-1	328688.58	2335823.18	347.07	Alum Cap & rebar
98026-2	328240.92	2337400.58	346.36	Alum Cap & rebar
98026-3	328354.33	2336776.48	346.89	H & T

NOTES

1. COORDINATE SYSTEM - WASHINGTON SOUTH STATE PLANE ZONE 4602 - HORIZONTAL DATUM - NAD 1927 VERTICAL DATUM - NGVD 1929 LINEAR UNIT - US SURVEY FOOT

2. HORIZONTAL CONTROL BASIS - W88-25-50, PASCO RADIO STA KALE CENTER TOWER, CR-9-RB

3. VERTICAL CONTROL BASIS CPAR-1 1975 LISTED ELEVATION 360.194

4. SURVEY PERFORMED ON 18 DEC. 1997 BY WALLA WALLA DISTRICT SURVEY AND MAPPING SECTION PERSONNEL

5. CONTOUR INTERVAL IS 0.5 FOOT WITH THREE MINOR PER MAJOR

LEGE

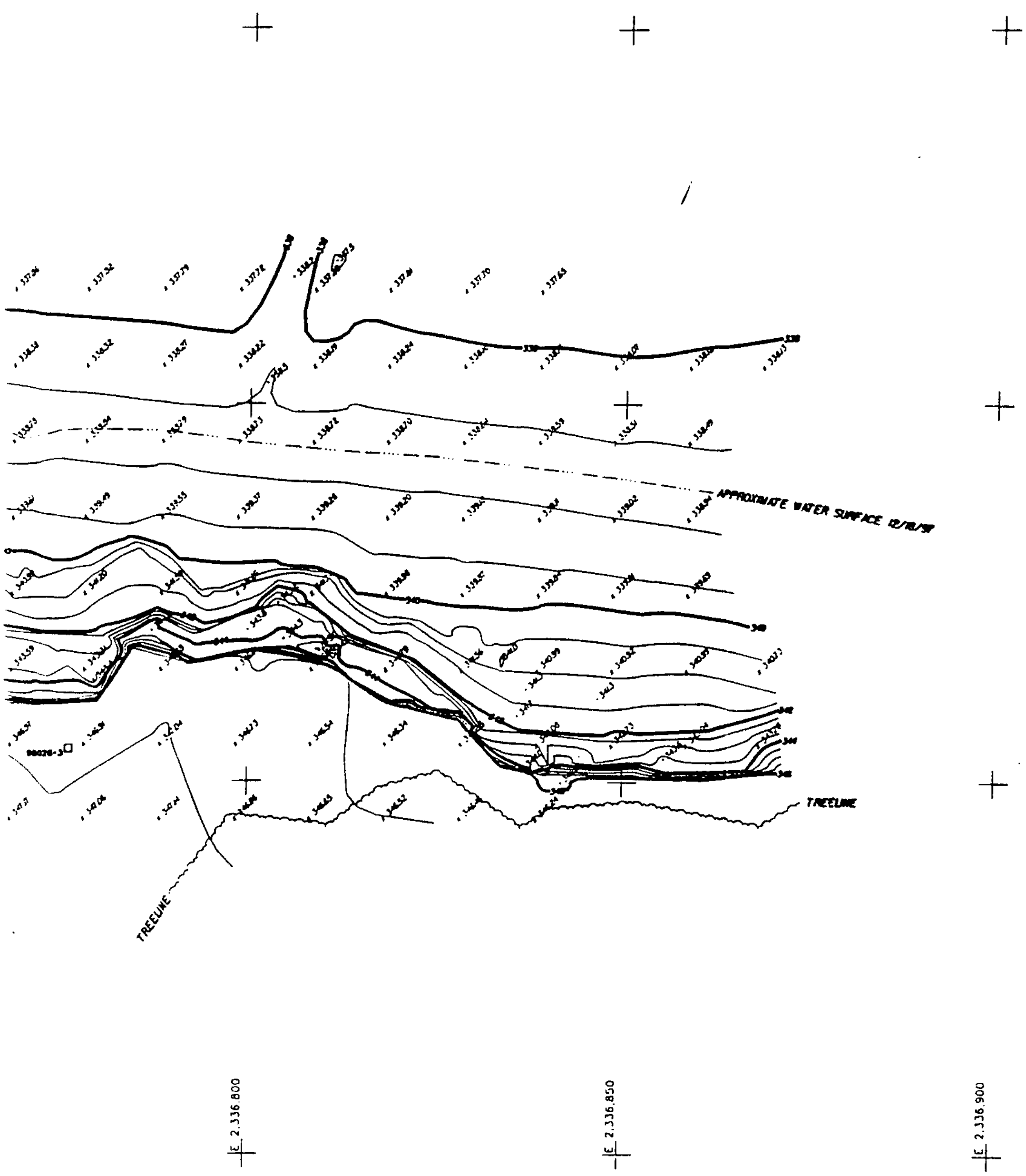
HUB

TREE

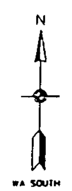
WATI

SCALE:

10' 0



LEGEND
- □ HUB & TACK
- ~ TREELINE
- - - WATER LINE



SCALE: 1"=10'
10' 0 10'

BONDURANT
MEYER

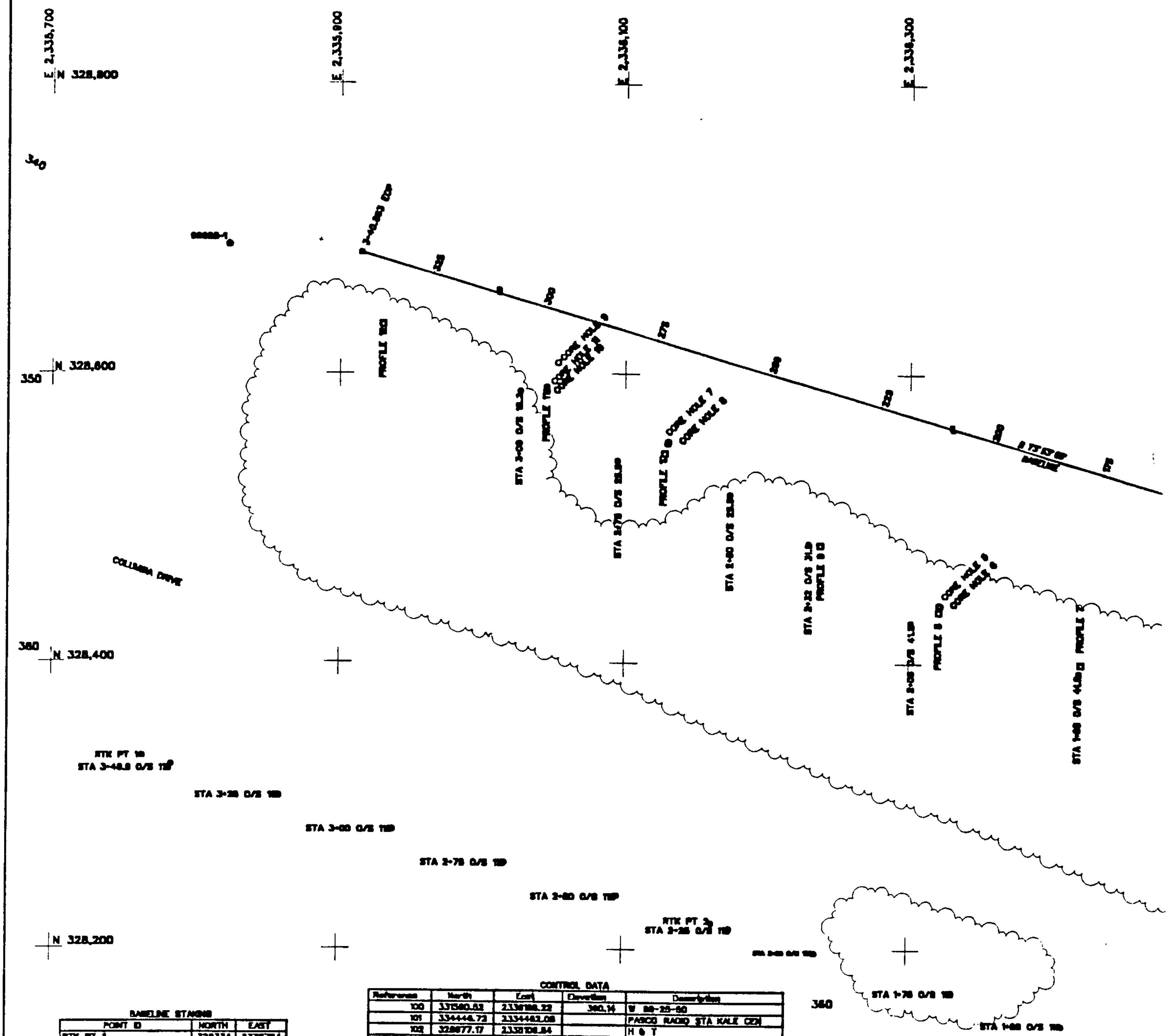
ANCIENT REMAINS SITE INVESTIGATION
KENNEWICK, WASHINGTON

RIVER BANK TOPOGRAPHY

1 OF 1 **97-67**

YES NO S S

F1



CONTROL DATA

Reference	North	East	Elevation	Description
100	331560.52	2336188.22	360.14	W 88-25-50
101	334444.72	2334482.06		PASCO RADIO STA KALE CEN
102	328677.17	2338108.84		H & T
103	330604.38	2337704.91	348.30	CR-9-R8
98028-1	328888.08	2336823.18	347.07	Alum Cap & rebar
98028-2	328246.82	2337400.58	346.38	Alum Cap & rebar
98028-3	328364.33	2336776.48	344.89	H & T

BASELINE STAKING

POINT ID	NORTH	EAST
RTK PT 1	328334	2336784
RTK PT 2	328318	2336183
RTK PT 3	328078	2336640
RTK PT 4	327857	2337080
RTK PT 5	327911	2337220
STA 0+00 O/S 115	328010	2336884
STA 0+25 O/S 115	328033	2336808
STA 0+50 O/S 115	328056	2336737
STA 0+75 O/S 115	328078	2336648
STA 1+00 O/S 115	328101	2336568
STA 1+25 O/S 115	328124	2336480
STA 1+50 O/S 115	328147	2336411
STA 1+75 O/S 115	328180	2336333
STA 2+25 O/S 115	328219	2336178
STA 2+50 O/S 115	328238	2336098
STA 2+75 O/S 115	328260	2336018
STA 3+00 O/S 115	328283	2335938
STA 3+25 O/S 115	328306	2335860
STA 3+48.8 O/S 115	328328	2335785
STA 0+00 O/S 38.8	328248	2336852
STA 0+25 O/S 38.2	328264	2336808
STA 0+17.5 O/S 13.1	328347	2336822
STA 2+06 O/S 41.8	328428	2336302
STA 0+25 O/S 24.0	328301	2336861
STA 0+00 O/S 18.7	328358	2336874
STA 0+20 O/S 32.0	328369	2336574
STA 1+25 O/S 32.0	328370	2336558
STA 3+00 O/S 15.3	328566	2336027
STA 2+75 O/S 26.9	328540	2336085
STA 1+00 O/S 38.2	328338	2336437
STA 0+70 O/S 27.9	328363	2336728
STA 0+50 O/S 27.9	328346	2336808
STA 2+50 O/S 26.8	328517	2336174
STA 2+32 O/S 31.8	328483	2336220
STA 1+48 O/S 41.8	328394	2336421
0+00 BOP BASELINE PT	328373	2336888
3+40.863 EOP	328583	2335918

BASELINE STAKES ARE FOR SITE ORIENTATION ONLY.
THEY ARE NOT TO BE USED FOR SITE CONTROL.

TIED POINTS

Description	North	East	Elevation
P	328338.80	2336797.87	347.3
PROFILE 1	328356.37	2336857.38	345.2
PROFILE 2	328306.88	2336826.22	346.3
PROFILE 3	328380.85	2336798.50	346.7
PROFILE 4	328368.01	2336714.83	346.3
PROFILE 5	328375.18	2336888.88	346.8
CORE HOLE 3	328366.12	2336798.34	338.0
CORE HOLE 4	328368.15	2336796.74	338.8
CORE HOLE 1	328377.20	2336844.18	338.5
CORE HOLE 2	328376.38	2336844.88	338.8
PROFILE 6	328382.30	2336556.07	348.0
PROFILE 7	328388.84	2336422.78	346.4
PROFILE 8	328438.21	2336321.11	347.0
CORE HOLE 6	328446.72	2336322.22	340.8
CORE HOLE 5	328440.88	2336321.38	340.8
PROFILE 9	328482.08	2336236.85	346.4
PROFILE 10	328548.83	2336127.48	346.3
PROFILE 11	328566.15	2336046.28	346.7
PROFILE 12	328633.88	2336029.88	347.1
CORE HOLE 9	328607.38	2336053.10	338.8
CORE HOLE 10	328591.86	2336044.17	341.3
CORE HOLE 11	328591.03	2336044.15	341.1
CORE HOLE 7	328553.53	2336120.86	338.9
CORE HOLE 8	328563.36	2336120.81	340.1
N107E968	328379.05	2336994.03	342.0
N107E100	328376.00	2336728.88	342.8
N106E118	328364.88	2336781.42	344.2
N107E118	328371.43	2336782.04	341.8
CORE HOLE 12	328367.32	2336774.81	343.0
CORE HOLE 13	328367.44	2336775.41	343.0

NOTES

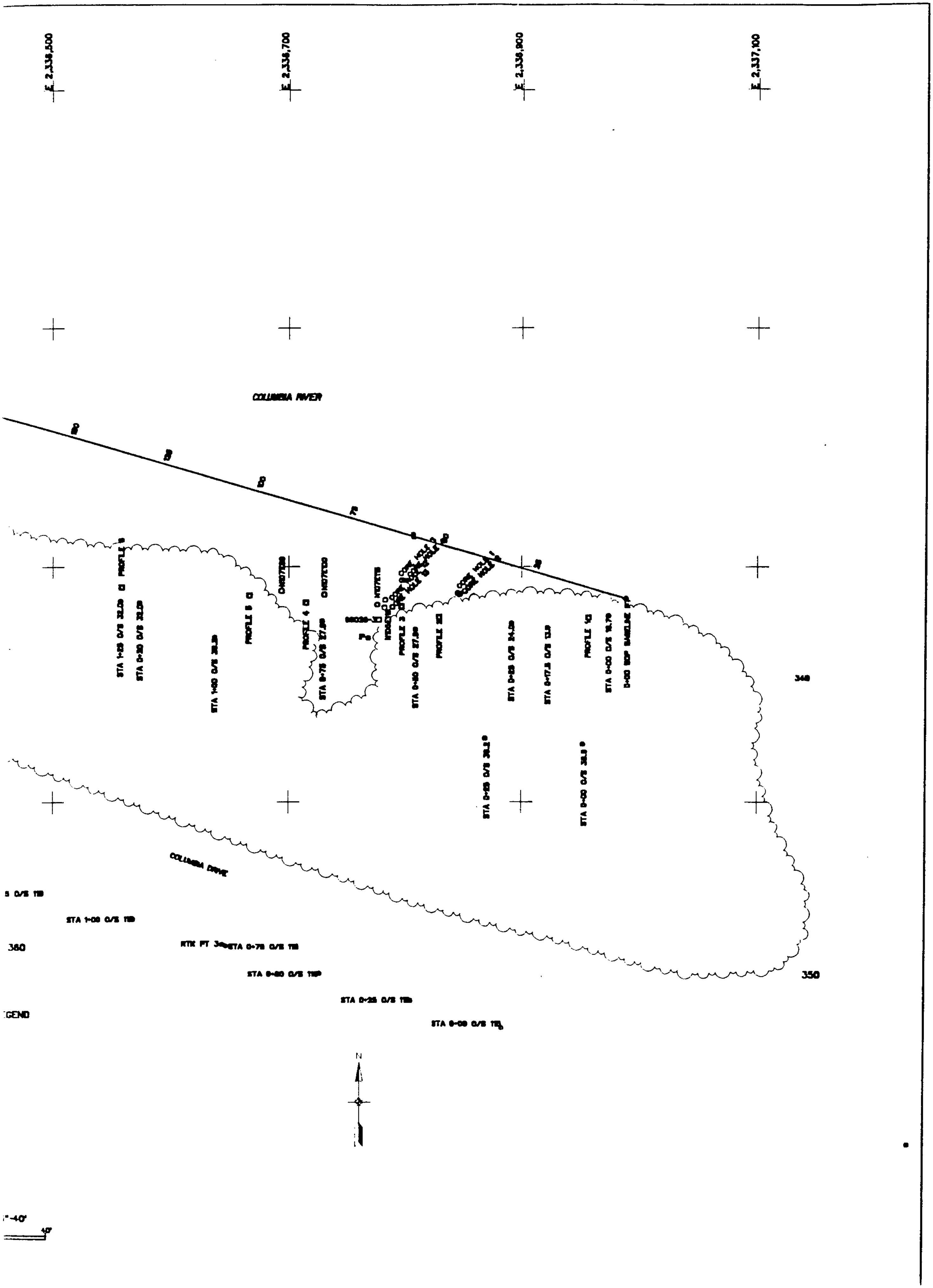
1. COORDINATE SYSTEM - WASHINGTON SOUTH STATE PLANE ZONE 4602
   HORIZONTAL DATUM - NAD 1927
   VERTICAL DATUM - NGVD 1929
   LINEAR UNIT - US SURVEY FOOT
2. BASE MAPPING FROM 1:24,000 AERIAL PHOTOGRAPHY
3. HORIZONTAL COORDINATE BASIS WB8-25-50, PASCO RADIO STA KALE CENTER TOWER, CR-9-R8
4. VERTICAL CONTROL BASIS CPAR-1 1975 LISTED ELEVATION 360.194

LEGEND

STA 1+25 O/S 1

380

SCALE: 1"=40'
40' 0


E 2,336,500
E 2,336,700
E 2,336,900
E 2,337,100
COLUMBIA RIVER
COLUMBIA DRIVE
348
350
360
STA 1-00 O/S 11B
RTK PT 34
STA 0-75 O/S 11B
STA 0-25 O/S 11B
N

F2

Appendix G

Ground Penetrating Radar Investigation
at the Kennewick Man Site,
Kennewick, WA,
Contributed by CH2M HILL Hanford Company,
Richland, WA

Cultural Resource Geophysical Investigation

Site: Kennewick Man. Columbia Park, Kennewick, WA
Date: 12-16-97
Sponsor (Contact, phone): Corps of Engineers, Vicksburg, Ms, Joe Dunbar, Lillian Wakeley, Fred Briuer, WES office, (601) 634-3215
Investigators (Name, Company, Phone, E-mail):
Tom Mitchell / CH2MHill / (509) 372-9690 thomas_h_mitchell@rl.gov
Kevin Bergstrom / CH2MHill / (509) 372-9591 kevin_a-bergstrom@rl.gov
Location: South shore of Columbia River along Columbia Park, Benton County, WA.
Objectives: To test applicability of using ground-penetrating radar (GPR) for more detailed studies at this site. Map shallow stratigraphy and shallow anomalies if site conditions (i.e. saturated mud) allow. Identify preferred locations to minimize the number of potential test pits.

Site Description

Cultural Setting: The site is along the shoreline of the Columbia River. A nearly complete human skeleton was found, with unconfirmed initial dates in excess of 9000 years old. A few additional artifacts have been observed in the area including arrowheads and flint knapping flakes.
Terrain: From the water edge inland: A gently sloping shore that is three to four meters wide consisting mostly of saturated soil and "mud" (normally under water). The shore is bounded by a one-meter high cutbank to the south and the edge of the river to the north. Above the cutbank there is a relatively flat terrace.
Vegetation: Several clumps of bunch grass are located along the shoreline. Annual weeds and perennial grasses, brush, dominate a relatively open area on the terrace above, which is surrounded by thick stands of deciduous trees.
Hydro Properties (water table, moisture etc.): For work below the cutbank, the ground was saturated with the water table at or within 0.5 meters of the surface, depending upon the proximity to the shoreline.
Soil/sediments/rock type: Organically rich silts with some clay. Few cobbles or rocks were observed in the area. Three-inch vibra-cores were easily driven to several meters depth. A thin ash layer was detected about 30-40 cm below the surface. Carbonate is only evident in about the upper one meter.
Anticipated Bedrock (depth and type): No bedrock outcrops are observed near the site. The uppermost basalt layers are over 100 meters below the surface.
Obstacles (rocks, trees, buildings etc): At high water, the river extends to the base of the 1-meter high cutbank. During lower water periods, one to five meters of relatively flat shore may be available. Large rocks, clumps of bunch grass, and river debris obstruct the shoreline in places. Above the cutbank, trees, heavy underbrush, and logs limits the areas that can be investigated using geophysical techniques. Much of the area on the terrace immediately above Kennewick Man site is relatively open.
Overall assessment of site for geophysical investigations: The GPR was marginally effective along the shoreline in the saturated sediments. Depth of investigation was limited to 0-1 meters along the shoreline. On the terrace above, the observed shallow sediments are relatively homogeneous silts which are good conditions for GPR investigations as confirmed by the few test profiles that were collected on the terrace. Due to saturated sediments, resistivity methods might work well along the shoreline. Other EM and magnetic survey methods need to be tested

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Equipment:

Type/model: Ground Penetrating Radar (GPR): GSSI Sir-10A Plus, 500 MHz antenna, mod. 5103, 300 MHz antenna, mod. 3105AP. Records printed on a GSSI 608P printer.

Data format (tape/disk/hardcopy): Electronic copies in GSSI format on a JAZZ drive. Hardcopies of each profile printed with a GSSI 608P printer.

Data Collection Parameters:

Survey Parameters/grid: Continuous scan GPR data were collected in two perpendicular directions. East-west profiles parallel to the river were spaced at 1 meter or less. North south profiles, perpendicular to the river were typically spaced 2 meters apart. The grid along the shoreline covered an irregular shaped rectangle, roughly 6 meters by 15 meters. Above the cutbank, about 1.5 meters above the water level, two random profiles were collected with the 300 MHz antenna.

Equipment Settings: A 54-nanosecond window was used for both the 300 and 500 MHz antenna. The scan rate was 25 scans/second.

Summary of Results:

(Data quality, types of information, etc.)

In general, GPR was marginally effective along the shoreline, but shows great promise up on the terrace. The effective depth of investigation was 0 to 1.0 meters along the shoreline. Some isolated debris, interpreted as metallic, was identified in the 0.5 to 0.8 meter depth range, which is within the saturated zone. This type of debris is consistent with scattered surface trash found in the vicinity. Several other isolated anomalous zones were identified that are of unknown origin but appear to be related to changes in the conditions of the soil.

Good data was collected in the 0-2 meter range on the terrace above the cutbank. Under these conditions GPR is usually effective for investigating the geologic substrata above and slightly into the saturated zone. The removal or "trimming" of the thick grass and brush that covered the open portion of the terrace would increase the quality of the GPR data in this area thus further increase its effectiveness.

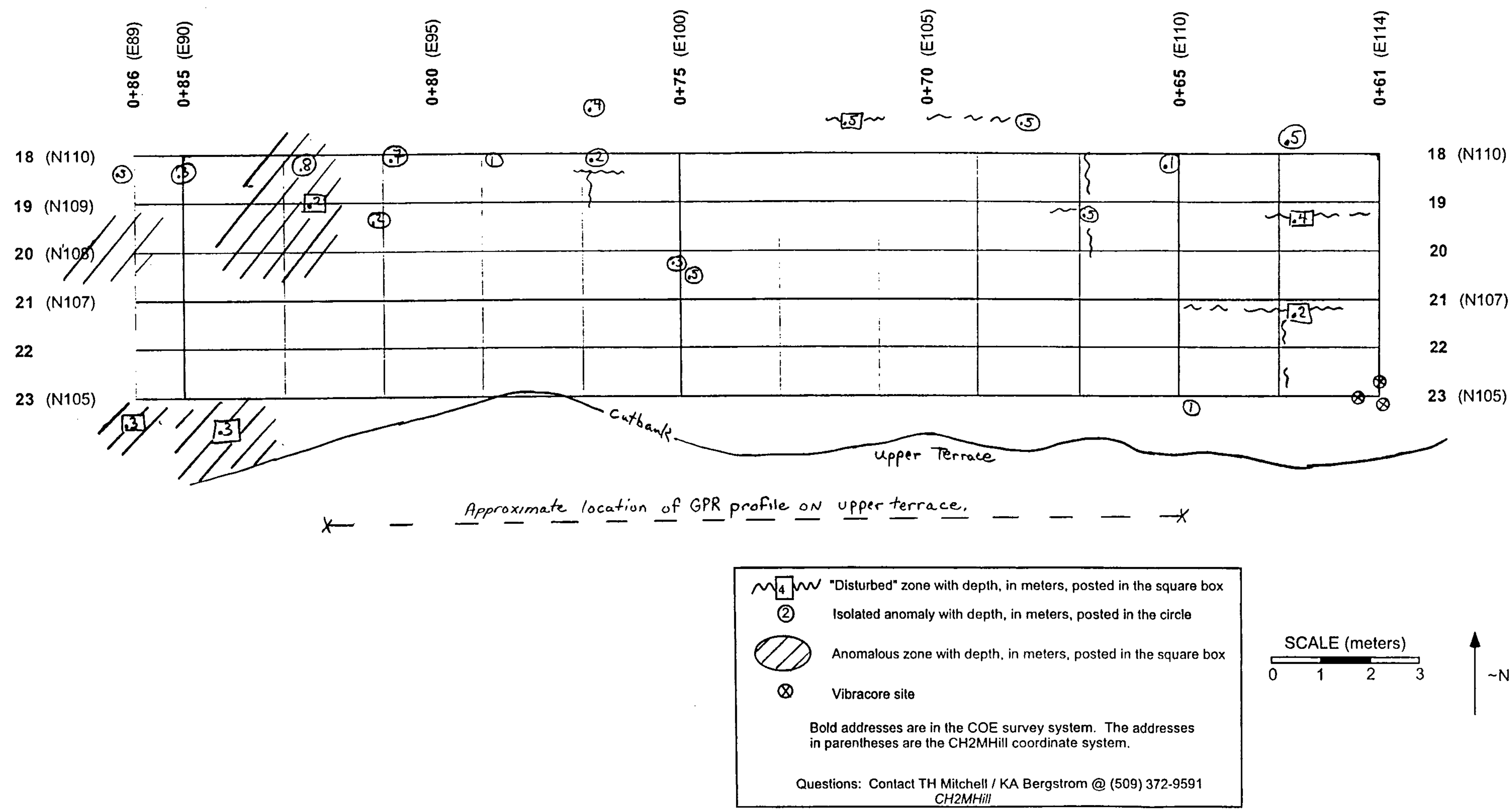
Based on the cutbank exposure of the soil horizons, the soils appear homogeneous, both laterally and vertically. This would suggest that the data would be nondescript, and that generally was the case. Several anomalous areas, on the order of a few decimeters deep and a few meters around, were identified in the data. These are areas where the character of the data is different than the overall character.

Lessons Learned/Recommendations

- Data collected along the shoreline did not appear to provide sufficient resolution to detect cultural features that are anticipated as having minimal physical contrasts with the surrounding soils. However, despite the saturated soil conditions, anomalous soil conditions, and high contrast features such as metal objects can be detected.
- The terrace above the shoreline shows great promise for detecting and mapping the more subtle anomalies that might be associated with cultural and geomorphic investigations.
- If the terrace were to be investigated with GPR or other geophysical techniques, it would be preferable to have the annual brush/weeds mowed/cut down to a few inches to provide for better coupling, which would significantly improve achievable data quality.
- Data should be collected on no greater than a one-meter grid spacing in at least 2 perpendicular directions.
- Geophysical methods might include GPR, EMI, magnetics, and possibly resistivity. These are all accepted methods for archaeological work.
- The GPR should be conducted at a minimum of two different frequencies. 300MHz has good overall resolution vs. depth of penetration characteristics. It should provide information on the upper two meters. A 500MHz antenna provides greater resolution and will probably provide information from the upper one to two meters.
- The electromagnetic induction (EMI) survey should use a high resolution tool such as the Geonic's EM38. It responds to anomalies down to about 1.5 meters.
- A magnetic gradiometer survey with greater than one gamma resolution will respond to magnetic anomalies. This is a very effective tool in many archaeological sites, but controlled testing is important at this site to determine if the magnetic background/clutter, from possible basalt cobbles, etc., would render it less useful.

- Direct contacting resistivity methods, such as the GEOSCAN RESEARCH Multi-probe array, may be good, but much depends on soil conditions. This wet/near-saturated site may be good for resistivity.
- Work out into the water should not be rigorously considered at this time since this site already is a difficult geophysical site, but brief testing could be conducted during the course of work.

G4



0+86 (E89)
0+85 (E90)
0+80 (E95)
0+75 (E100)
0+70 (E105)
0+65 (E110)
0+61 (E114)
18 (N110)
19 (N109)
20 (N108)
21 (N107)
22
23 (N105)
18 (N110)
19
20
21 (N107)
22
23 (N105)
Cutbank
Upper Terrace
Approximate location of GPR profile on upper terrace.
"Disturbed" zone with depth, in meters, posted in the square box
Isolated anomaly with depth, in meters, posted in the circle
Anomalous zone with depth, in meters, posted in the square box
Vibracore site
Bold addresses are in the COE survey system. The addresses in parentheses are the CH2MHill coordinate system.
Questions: Contact TH Mitchell / KA Bergstrom @ (509) 372-9591
CH2MHill
SCALE (meters)
0 1 2 3
~N

File 3: N108SW2E(12/16/97 12:12:06)
Samp/Scan 512 Scan/Sec 25.0 Bits: 8
COLUMBIA PARK KENN MAN

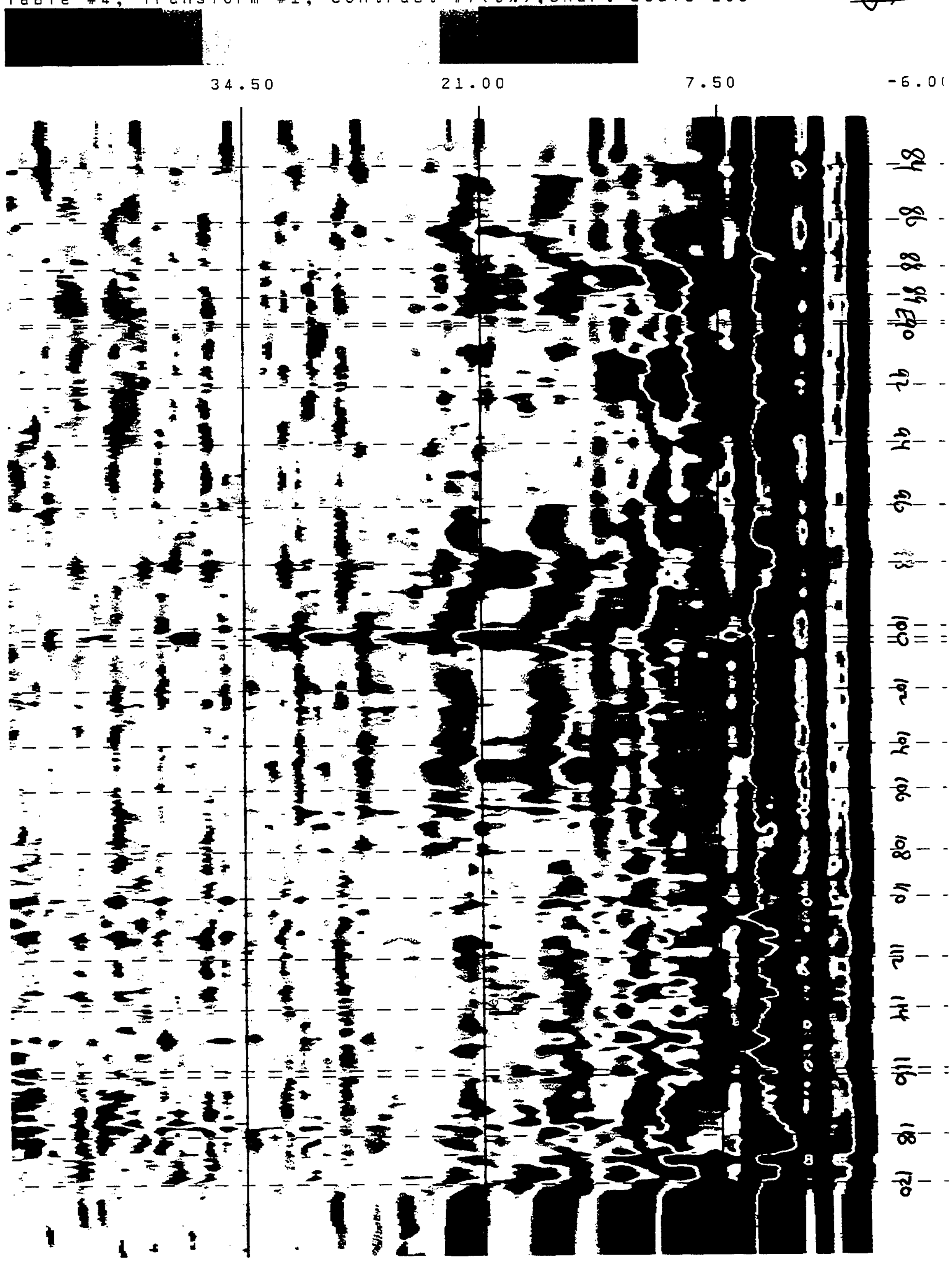
1 METER between marks

RANGE E90 TO

Position: -6.0nS Range: 54.0nS
Range Gain 10 19 28 38 48
V(IIR LP N=2 F=32)
V(IIR HP N=2 F=10)
H(IIR STK TC=3)

Table #4; Transform #1; Contrast #7(0%);Chart Scale 203

N108 $



G5

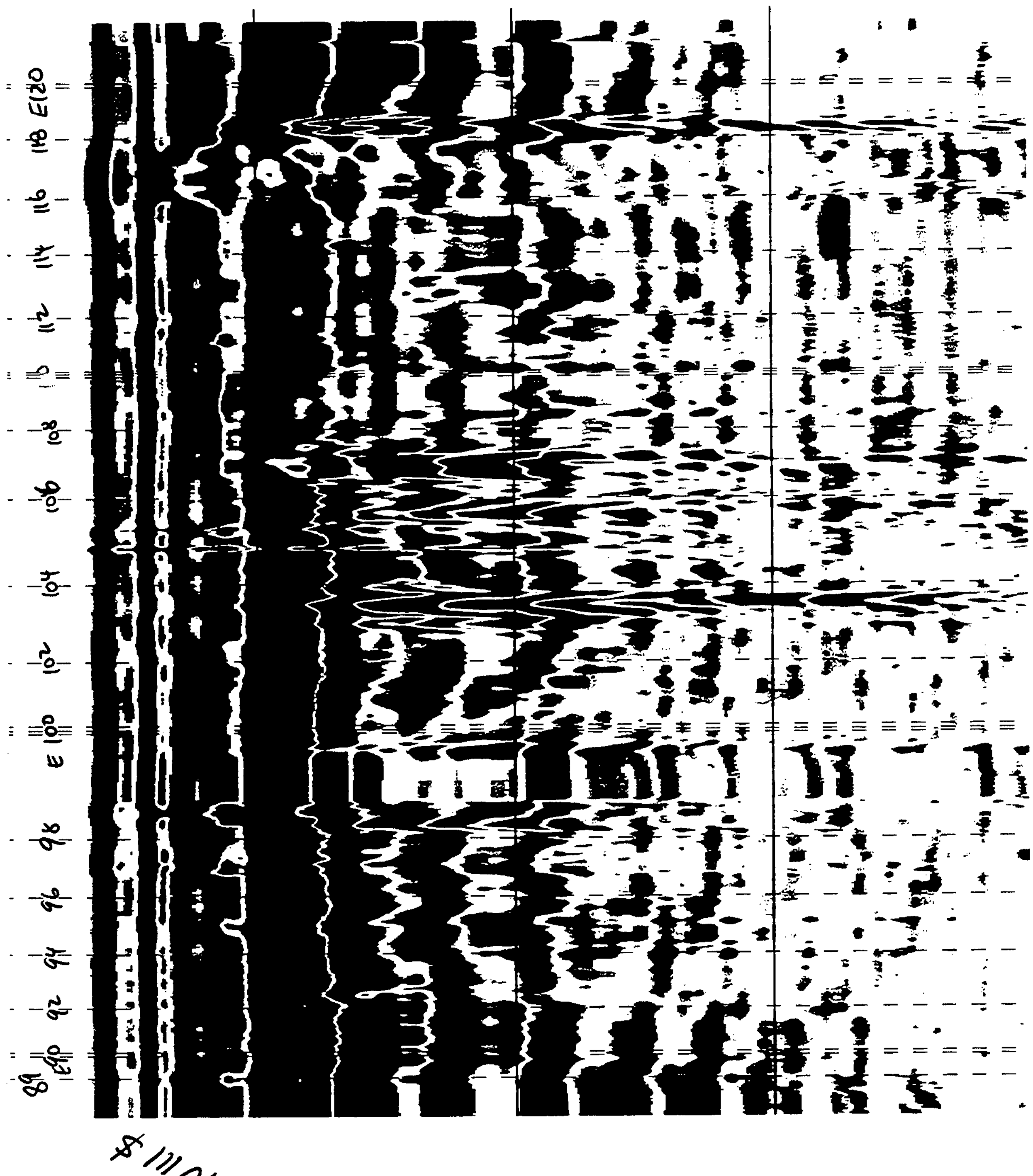
ile 6: N111SE2W(12/16/97 12:23:02)
amp/Scan 512 Scan/Sec 25.0 Bits: 8
OLUMBIA PARK KENN MAN

METER between marks

ANGE E90 TO

osition: -6.0nS Range: 54.0nS
ange Gain 10 19 28 38 48
(IIR LP N=2 F=32)
(IIR HP N=2 F=10)
(IIR STK TC=3)

able #4; Transform #1; Contrast #7(0%);Chart Scale 203



G6

ile 8: N100SE2W(12/16/97 12:45:18)
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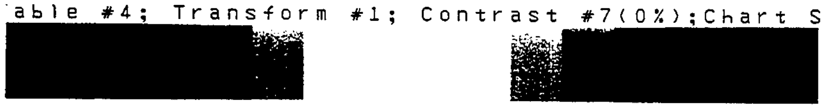
OLUMBIA PARK KENN MAN

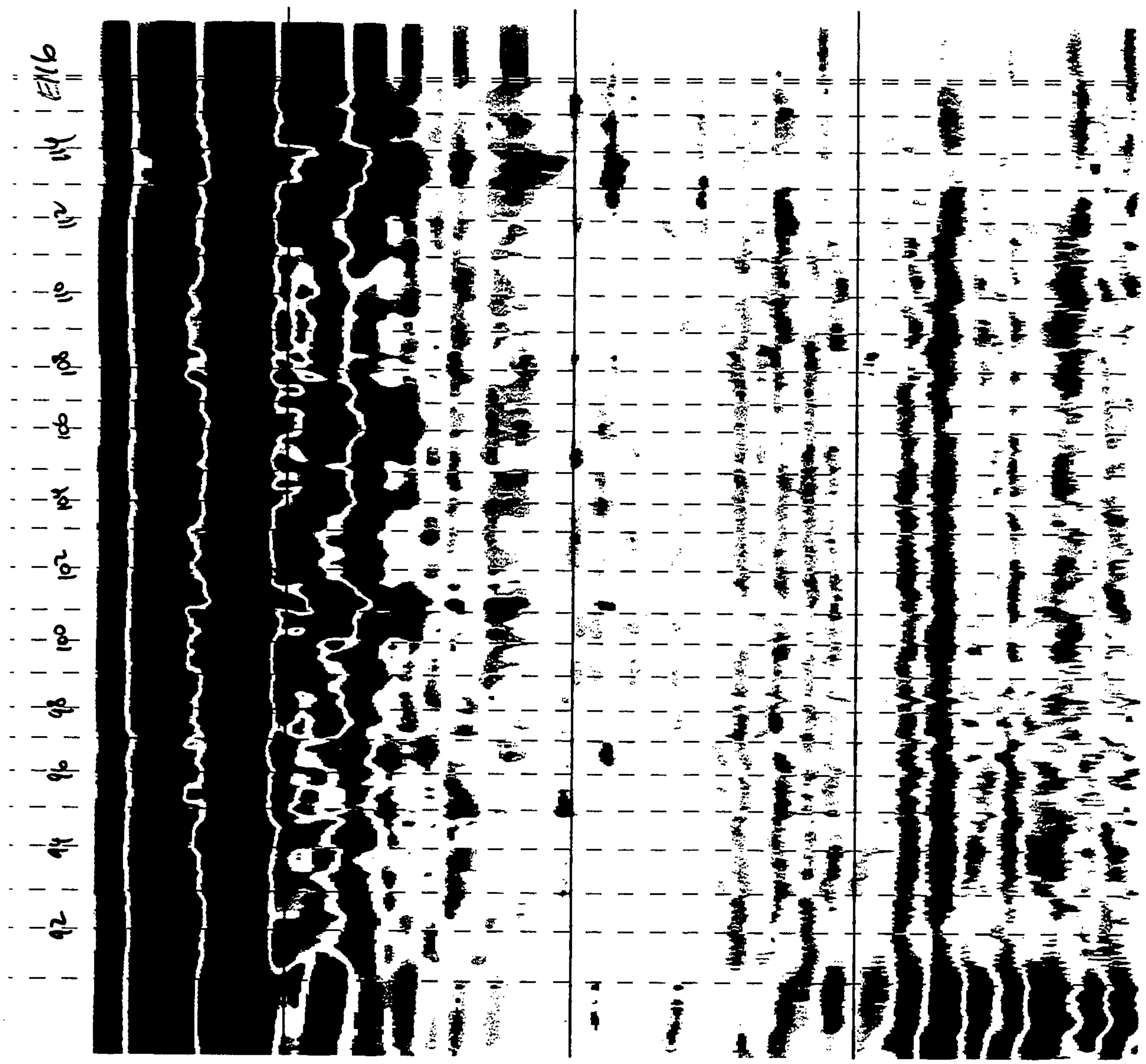
METER between marks

ANGE E90 TO

osition: -6.0nS Range: 54.0nS
ange Gain 10 19 28 38 48
(IIR LP N=2 F=32)
(IIR HP N=2 F=10)
(IIR STK TC=3)

able #4; Transform #1; Contrast #7(0%);Chart Scale 203





Upper Terrace
N100

Appendix H

Tephrochronology Report,
Contributed by Dr. Andrei M. Sarna-Wojcicki,
Chief, Tephrochronology Laboratory,
U.S. Department of the Interior Geological Survey,
Menlo Park, California

United States Department of the Interior
GEOLOGICAL SURVEY
Geologic Division; Regional Geologic Mapping Team, Western Region

Tephrochronology Laboratory

MS 975; 345 Middlefield Road, Menlo Park, CA 94025; Tel. 415 329-4930;
FAX: 415 329-4936; email: asarna@isdmnl.wr.usgs.gov

January 30, 1998

Bill Murphy
Acting Chief, Engineering Geology Branch
Waterways Experiment Station
U.S. Army Corps of Engineers
3909 Halls Ferry Road
Vicksburg, Miss. 39180-6199

Dear Mr. Murphy:

We have finished analysis of the sample of volcanic ash you sent to us on Jan. 16 of this year. This is the sample of "...Tephra collected at the west (upstream) end of the 'Kennewick Man' study site at Columbia Park, Kennewick, Washington...," as you described in your letter. We confirm the identification of this ash bed as the Mazama ash, erupted from the area of Crater Lake, Oregon, approximately 6,700 (^{14}C) years before present. I enclose documentation that supports this identification. For our purposes (storing the sample in our data base) I assigned the sample name "KEN-CE-1" to the sample of this volcanic ash.

Andrew (Drew) Eriksson of our lab and I examined the sample under the petrographic microscope. Drew separated the volcanic glass and prepared the sample for analysis. Charles E. Meyer of our lab analyzed the sample using our JEOL 8900 electron-microprobe. I evaluated the data and wrote this report.

The sample contained the following components (refer to the attached "Explanation of Data Sheets," and the two sheet report "Petrographic Description of Sample and Log of Procedures..."): about 65% pumiceous glass shards, 10% volcanic lithic grains (and other, rounded lithic grains that are probably detrital material mixed in with the ash), about 20% plagioclase feldspar, and about 5% augite, hypersthene, and hornblende, magnetite, and a trace of apatite. Many of the grains were coated with a finely-crystalline calcite (?) cement. Rounded detrital (?)

lithic grains and other unidentifiable irregular grains were also present. Most of the euhedral and angular minerals (plagioclase, augite, hypersthene, hornblende, magnetite and apatite), had glass coatings adhering to their surfaces or were encased in glass shards, indicating that they were "primary," that is, were crystallizing from the magma before the eruption. The mineral suite is compatible with that of the Mazama ash bed (Sarna-Wojcicki and others, 1983; Davis, 1978). The calcite that showed up in the X-ray diffraction pattern obtained by Dr. Lillian Wakeley is probably authigenic calcite cement that we see under the microscope. The quartz pattern that she obtains is very likely from detrital material that was river alluvium entrained in the ash during deposition. I saw little or none of this in the grain mounts, but it may have been finely-divided, chalcedonic, quartz.

Charley analyzed 20 individual grains (shards). Of these, 14 formed a coherent population with high totals and similar compositions, and these were averaged, and the average was compared with our data base of analyzed samples using a computer program and a similarity coefficient. The remaining 6 shards had either anomalously low totals (Excel table labeled "KEN-CE-1 T376-1" at top of table), suggesting that thin, frothy walls of shards had been analyzed; or the shards had anomalously high aluminum and sodium, and low silica concentrations, suggesting plagioclase feldspar microlites or microphenocrysts within the glass had also been hit by the electron beam, in addition to the volcanic glass.

The sheets comparing the analysis of KEN-CE-1 to other samples in our data base (we have now about 4,100 probe analyses of tephra samples from the U.S.) indicate an excellent match with the Mazama ash bed. Below, I compare the average values of the elements, expressed as oxides, to the average of 94 samples of the Mazama ash bed. The latter set consists of documented samples of the Mazama, culled of any samples that may be questionable.

Sample	SiO2	Al2O3	Fe2O3	MgO	MnO	CaO	TiO2	Na2O	K2O	Total,R
KEN-CE-1	72.83	14.60	2.07	0.44	0.04	1.55	0.41	5.33	2.74	100.01
n(shards)=14; ±s	0.38	0.22	0.07	0.02	0.02	0.07	0.05	0.13	0.06	0.54
Mazama Av.	72.79	14.65	2.12	0.46	0.05	1.61	0.42	5.19	2.71	100.00
n(samples)=94; ±s	0.35	0.23	0.04	0.02	0.01	0.06	0.02	0.18	0.08	n.d.

The match is excellent, within the errors of the analytical method. There are no known tephra layers, other than the Mazama, that have this

particular composition. There are several other tephra layers that have similar compositions; all are older, and all were erupted from the Crater Lake, Ore. area. Thus, the identity of this unit, in my opinion, is quite secure.

The latest reported, revised age of the Mazama ash bed is 6,730 ±40 ^{14}C years B.P., based on accelerator mass spectrometry and a review of previous literature (Hallett and others, 1997). Please refer to the matching sheets, enclosed, that show some other close matches (Listing of 50, 100 closest matches for the sample). Among some of the specific closest matches are samples of the Mazama ash bed from north-central and central Washington (STEM-3, from Stemen; RC92-2, from the Ribbon Cliff landslide upstream on the Columbia River; Madole and others, 1995).

Of some interest to you with regard to the current study of Kennewick Man may be J.O. Davis' 1978 study, in particular his locality JOD16 in NW Nevada, where Mazama ash bed is found to overlie archeological finds in the "Last Supper Cave" (see p. 83 of Davis, 1978). There, the Mazama ash bed ovelies Parman and Cougar Mountain projectile points, and charcoal dated at ~8,960 and 8,260. Northern Side Notched and Pinto series projectile points and a charcoal sample radiocarbon dated at 6,905 come from the tephra layer. Elko, Eastgate, Rose Springs, Desert Side Notched, and Humboldt Concave Base projectile points and charcoal dated at 1,545 and 1,043 yrs B.P. overlie the layer.

If you have any further question, or if you would like to discuss the results further, please call me or mail me at any of the above addresses. I will have our Admin. Assistant, Mary Ann Rouse, send a billing to you for the cost of the analysis.

Sincerely,

Andrei M. Sarna-Wojcicki

Andrei M. Sarna-Wojcicki,
Geologist, Chief, Tephrochronology Laboratory

Copy to: Dr. Lillian Wakeley,
Waterway Experiment Station,
U.S. Army, Corps of Engineers,
Address as above.

References:

Davis, J.O., 1978, Quaternary tephrochronology of the Lake Lahontan area, Nevada and California. Nevada Archeological Survey Research paper No. 7, University of Nevada, Reno, July. See p. 83-85; 101, etc.

Hallett, D.J., Hills, L.V., and Clague, J.J., 1997, New accelerator mass spectrometry radiocarbon ages for the Mazama tephra layer from Kootenay National Park, British Columbia, Canada. Canadian Journal of Earth Sciences, v. 34, p. 1202-1209.

Madole, R.F., Schuster, R.L., and Sarna-Wojcicki, A.M., 1995. Ribbon Cliff landslide, Washington, and the earthquake of 14 December 1872. Bulletin of the Seismological Society of America, v. 85, n. 4, p. 986-1002.

Sarna-Wojcicki, A.M., Champion, D.E., and Davis, J.O., 1983, Holocene volcanism in the conterminous United States and the role of silicic volcanic ash layers in correlation of latest-Pleistocene and Holocene deposits. In Wright, H.E., ed., Late-Quaternary Environments of the United States, v. 2, The Holocene, University of Minnesota Press, Minneapolis. See Chapter 5, Table 5.2, and Figs. 5.2, 5.9.

I believe that Dr. Wakeley has our 1991 references from the DNAG vol. K-2 (Sarna-Wojcicki and Davis, and Sarna-Wojcicki and others).

Explanation of Data Sheets, Petrographic and Electron-Microprobe Analysis, and Data Evaluation

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August 21, 1997

Data Sheets

I enclose four or more data sheets for each sample that has been processed and analyzed in our lab:

The first sheet(s): is a brief petrographic description of the sample made during an initial examination on coming into the Tephrochronology Laboratory. This first look is to see what is in the sample, to check for the presence of volcanic glass shards, to determine the state of preservation of the glass (are the glass shards clear, clean and isotropic? coated? hydrated? devitrified? altered?), and to describe the minerals present, whether they are likely to be comagmatic or not, and to note the presence of other components such as lithic fragments, organic material, microfossils, etc. This exam determines the type of processing needed to separate the glass, assuming we decide that the glass is sufficiently preserved to analyze. The rest of this description lists the steps taken during disaggregation, sieving, ultrasonic vibration, acid treatment, and magnetic and heavy-liquid separations. Often the minerals can be more easily identified and shard morphologies described after some initial treatment. An explanation of some of the abbreviations we use on this sheet is given below:

WS: Wet sieved. See below [-100+200] for size fraction used for separation and analysis. (-) refers to less than the mesh specified, (+) refers to greater than the mesh specified. The mesh sizes are for nylon screens, not standard metal screens. Common sizes used by us are 100 (150 µm), 200 (80 µm), and 325 (45 µm) meshes.

HAND MAG: A hand magnet was used to remove the highly magnetic minerals, magnetite and ilmenite, or lithic grains/shards containing these minerals.

FRANTZ: Frantz Magnetic Separator. Usually two runs, at a higher and a lower amperage, at settings indicated (e.g., 0.2a, for amperage; +8°, for side tilt; forward tilt is usually about 22°). Middle fraction usually contains most of the volcanic glass shards.

HCl: Dilute HCl bath (10%), for time indicated (in seconds), to get rid of authigenic carbonate cement or coating on, and in vesicles of, shards, and on mineral-grain surfaces.

HF: Dilute HF bath (8%), for time indicated (seconds), to clean the surfaces of glass shards and minerals of clay or other coating.

TUBE: Differential gravity tube, using mixtures of methylene iodide and acetone, to separate glass shards from other components in the tephra samples. Tb, Tm, Tt, are density fractions from bottom, middle, and top of liquid column, respectively.

VIBE: Ultrasonic vibrator, in deionized water, for time indicated, in seconds.

Additional information gives date sample was given to Charley Meyer for electron-microprobe analysis (EMA), if isotropic glass was present, and curatorial information regarding sample storage. Usually, we reserve some of the unprocessed sample for a reference collection, and the various other separates are also retained and curated in separate copllections for dating, follow-up ana;ysis, etc.

The second sheet(s): contains all the initial individual analytical data: all the points that Charles Meyer analyzed by EMA, the ones he selected to average as a single, relatively homogeneous group, and the associated statistics. Outliers, analyzed points on glass shards that were not used in calculating the averages, or points on minerals or microlitic glass that deviate highly from the major mode, are listed separately. Occasionally, Charley detects two or more compositional modes within a single sample, in which case the averages and other statistics for these modes are calculated separately, and entered into the data base separately.

The third sheet(s): (data recalculated by a FORTRAN program) is our "updateema.out" sheet, that we obtain after we imput the new averages of data on discrete compositional modes of a new sample into our data base. As mentioned above, most samples have only one compostional mode, with or without outliers, but some samples contain multiple compositional modes, and these are entered as separate samples. This sheet shows the actual average for the oxides we obtained in analysis, culled of any outliers or suspicious data points, and contains the original total [TOTAL(O)]. We imput the iron into our data base as FeO, then covert it to Fe2O3, and recalculate the total [TOTAL(N)] Then the oxides are "normalized" (recalculated) to 100%, and summed [TOTAL(R)]. The last total is usually somewhere between 99.99 and 100.01, because of a rounding error.

We normalize the oxides to 100 % because volcanic glass is usually hydrated to some extent--anywhere between a fraction of a percent to 10 % or more. Recalculating the oxides to 100 % eliminates errors introduced by differential hydration of volcanic glass of the same tephra unit at different depositional/natural "storage" sites. The original total is a good guide to the degree of hydration of the glass. Totals near 100 % indicate little or no hydration has taken place (common for late Holocene or modern glass). Low totals indicate a high degree of hydration of the glass, often found in older tephra units, or in units which have been deposited or stored in a "glass-unfriendly" environment--for

example, in an alkaline lake, acidic bog, or within a highly waethered soil profile or in sediments that have been repeatedly alternately wetted and dried. We have obtained totals as low as 90%, and even 85%, on glasses that still appear to be optically isotropic (i.e., not devitrified). On analysis, such samples often have very anomalous alkali concentrations, and may also show some enrichment or depletion of alkali-earth or transition elements.

Below this set of data is a column showing the 20 best matches to samples in our data base (using the similarity coefficient of Borchardt and others, 1972). Because samples are entered into the data base sequentially, the first sample will not be matched with the ones entered after it during a particular data-entering session, so we generally ignore this "20 Best Matches," except as a preliminary indicator of what units the sample may correlate with based on data already present in the data base.

The fourth and subsequent "matching sheets": (a FORTRAN matching program) is the "recompute.out" sheet, a program that we run after we have finished entering a new data batch. At this point all the data, new and old, is in the data base, and we run this program using the six major oxides: SiO_2, Al_2O_3, Fe_2O_3, CaO, Na_2O, and K_2O, comparing any specific sample in the data base with every other sample, including those in the latest batch of analyses. The program lists the compositionally closest samples, ranking them from the most similar, down, using the similarity coefficient. I usually ask for about 38 comparisons, because that's how many will fit on a single sheet in our particular set-up. This program may be run forward or backward (unknown matched to knowns, or known matched to unknown), to see how the rankings hold up.

I examine this sheet, and the closest matches, then often re-run the recompute program using a different set of oxides--for example, I will add MgO or TiO_2, if they are present in concentrations of about 0.15 percent or greater. Occasionally but rarely we use MnO, if the concentration is high enough, or if there are large differences (factor of two or more, but above about 0.08 percent) between candidate samples. If the sample is older than latest Pleistocene or Holocene, I might run a recompute without the alkalies, to see if samples match better that way. This is a way of getting around the post-depositional cation exchange and alteration/devitrification problem in volcanic glasses. In general, if the glass is not altered or devitrified, but if some hydration and alkali mobility has taken place within the glass, comparisons that include the alkalies will tend to show correlative layers that have been preserved within a similar geochemical (and thus, climatic) environment, while comparisons without the alkalies may indicate similarities among samples of the same unit that have had different natural storage environments.

Data Evaluation and Identification of Correlative Units

The closest matches, arranged in order of similarity for the oxides specified, form a pool of candidate correlative samples that are then examined by me, and if necessary, by whomever is most familiar with the specific stratigraphy, field setting, and other quantitative and qualitative age information relating to the sample(s) in question. Homotaxial succession, the repetition of specific compositional types of tephra layers in the same stratigraphic order at many different sites, provides a strong line of evidence for correlation of any one particular tephra layer found in such a sequence. This type of evaluation is undoubtedly one of the most critical steps in tephra correlation. Based on an evaluation of all the above data, probable correlations are identified, with any qualifications that are appropriate.

Basically, the main point here is that I view tephrochronology as a chrono-stratigraphic technique that must be applied within a larger geologic context and in light of multiple, independent lines of evidence. Unfortunately, tephro-chronology is not a "black box" technique that unfailingly provides a simple and unambiguous match through the "wonders of modern technology." *Tant pis.*

Follow-Up Analysis

Several orders of variability exist within the compositional spectrum of volcanic glasses. The greatest compositional differences exist between silicic and basic volcanic glasses, even within the same volcanic province. Eruptions of basaltic taphra are usually small and of limited extent, and thus such tephra is usually found locally; it can help resolve correlation problems within a small area, but not on a regional scale. Silicic tephra layers ($SiO2 > 65\%$; and especially $>70\%$) can be much more widespread. Among these layers, greatest differences are seen among different volcanic provinces. Tephra layers erupted from the same volcanic province tend to be more similar. Tephra layers erupted from the same volcanic edifice or vent tend to be even more similar. Generally, but not always, samples taken from the same tephra layer show the greatest similarity of all. Tephra layers erupted from the same volcanic province or the same series of volcanic vents tend to form a "family" of layers that are chemically similar, and can be difficult to distinguish by petrography or any one analytical technique (e.g., tephra of the Mono Craters, Calif.).

If a tephra layer has one major compositional mode, it can be analyzed by techniques other than electron-microprobe analysis (EMA). These techniques generally require a larger initial sample for processing, and a very pure separate of glass must be obtained for analysis, from 0.1 to 3 g of glass, depending on technique. A determination of the homogeneity of the glass, however, must be made by EMA, before any such more precise bulk analyses are made. There is no point in analyzing arbitrary mixtures of compositional modes, because unique or characteristic compositions cannot be identified in this way (unless the

"polymodality" is negligible). Techniques that provide better precision for the minor and trace elements than EMA are both energy-dispersive and wavelength-dispersive X-ray fluorescence (ED XRF; WD XRF), instrumental neutron-activation analysis (INAA), and inductively-coupled plasma mass spectrometry (ICP-MS). Any or all of these techniques can be used to characterize, identify, and correlate tephra layers, but time, labor, and expense are factors that need to be considered.

An alternative to correlation is direct dating of tephra layers, where suitable materials for dating can be obtained: i.e., sufficiently coarse comagmatic mineral grains, absence of xenocrystic or detrital contamination, and the appropriate age interval for the dating technique chosen in a given instance. Paleomagnetic characterization of the units or associated sediments can help in identifying correlative units as well.

The two approaches, correlation and direct dating, work hand in hand to provide chronostratigraphic data. Correlation by chemical characterization makes it unnecessary to attempt to date every exposure of a particular tephra unit where age control is needed, and provides correlated age data to sites where direct dating is not possible or not advisable.

For further information on Tephrochronology, refer to Sarna-Wojcicki and Davis, 1991, and Sarna-Wojcicki and others, 1991 (in Morrison, R., ed., Vol. K-2, Quaternary Nonglacial Geology: Conterminous U.S. The Geological Sociaty of America; Chapter 5). These articles contain many other references to tephrochronology and related topics.

PETROGRAPHIC DESCRIPTION OF SAMPLE AND LOG OF PROCEDURES USED IN SEPARATION OF VOLCANIC GLASS SHARDS AND PREPARATION FOR ELECTRON-MICROPROBE ANALYSIS

U.S.G.S. TEPHROCHRONOLOGY PROJECT

SAMPLE: KEN-CE-1
COLOR: Pale yellowish brown
DISAGGREGATION: Water spray

WS	FRANTZ	HCl	HF	TUBE
X	0.3a+8° 1.9a+8°	60	10	X

* Bioturbated, ca. 8"- thick ash, ~ 18" below ground surface, in stream terrace, South bank of Columbia River, by Wallula Res., Columbia Park, in Kennewick, Washington. Above "Kennewick Man" (~9,200 year B.P. archeo. site) See Kennewick 7.5 min. Quad., in folder KEN-CE-1

Spl: [-100+200]: There is a large concentration of glass, but the percentage is hard to tell due to heavy calcite coatings on all grains. NEXT ACIDS.

ACIDS: HCl-60, HF-10: All the grains were cleaned up nicely. 20% feldspars. 5% consists of a augite, hblde, and hypersthene which appear mainly as phenocrysts. 10% volcanic lithic grains. 65% pumaceous glass shards. 50% of the glass consists of bubble wall junction shards. 20% of the shards are pumaceous piped to spindled shards. The remaining 30% of the shards have rounded to irregular vesicles that are in abundance. Traces of opaque grains (most probably magnetite).NEXT FRANTZ.

FRANTZ: 0.3a+8°: MAG- 30% magnetite. 20% volcanic lithic grains. ~7% hypersthene. ~3% augite. Traces of hblde and feldspars. 25% altered and or coated glass that is dark and dirty. 15% pumaceous clean glass that contain phenocrysts of augite, hypersthene, and magnetite. NONMAG- 15% feldspars. 5% volcanic lithic grains. 80% pumaceous glass shards. Traces of light brown pumaceous glass.

FRANTZ: 1.9a+9°: MAG- 5% feldspars. 5% hblde. 5% volcanic lithics. 85% glass shards of which 40% contain phenocrysts (augite and hypersthene). NONMAG- 20% volcanic lithics. 80% feldspars. NEXT TUBE.

TUBE: -Tb- 20% volcanic lithics. 30% feldspars. 5% hblde. 25% glass shards that contain phenocrysts. 20% clean , pumaceous glass shards w/out phenocrysts. Tt- 99% pumaceous glass shards. Tt DONE FOR PROBE.

DONE FOR PROBE: 1/23/97

RS- 323

C- 226: 4 VIALS: [+100]; [-200+325]; 1.9a-M; 0.3a-M/1.9a-N/Tb.

Tephrochronology Lab 650-329-4939
National Geologic Mapping Program
U.S. Geological Survey
345 Middlefield Road MS 975
Menlo Park, CA 94025

7a

KEN-CE-1 T376-1

No.	Na2O	MgO	Al2O3	SiO2	K2O	CaO	TiO2	MnO	FeO	Total
13	5.052	0.422	14.317	70.532	2.597	1.437	0.365	0.015	1.708	96.445
14	5.074	0.418	14.386	70.918	2.734	1.510	0.356	0.000	1.755	97.151
15	5.223	0.439	14.407	70.658	2.641	1.510	0.498	0.063	1.823	97.262
17	5.254	0.431	14.309	70.297	2.630	1.599	0.316	0.055	1.783	96.674
18	4.945	0.467	13.673	70.500	2.579	1.454	0.453	0.041	1.873	95.985
19	5.172	0.427	14.366	70.722	2.610	1.604	0.408	0.013	1.879	97.201
21	5.158	0.416	14.181	70.959	2.726	1.625	0.404	0.016	1.738	97.223
23	5.343	0.417	14.093	70.945	2.630	1.449	0.450	0.054	1.807	97.188
24	5.003	0.416	13.972	70.056	2.741	1.462	0.414	0.055	1.725	95.844
25	5.294	0.422	13.957	71.392	2.601	1.461	0.462	0.031	1.810	97.430
26	5.231	0.456	13.969	71.333	2.651	1.500	0.334	0.028	1.925	97.427
27	5.409	0.406	14.381	70.775	2.648	1.522	0.380	0.046	1.771	97.338
29	5.212	0.381	14.277	71.231	2.782	1.409	0.401	0.036	1.859	97.588
30	5.180	0.467	14.287	70.581	2.670	1.505	0.394	0.032	1.856	96.972
NOT USED										
22	6.621	0.211	19.549	66.252	1.446	3.860	0.226	0.025	1.141	99.331
28	5.959	0.120	19.510	57.793	1.194	4.762	0.197	0.031	0.732	90.298
16	4.750	0.407	13.516	68.242	2.679	1.417	0.215	0.037	1.682	92.945
20	4.912	0.412	13.460	69.783	2.607	1.351	0.321	0.025	1.736	94.607
11	5.745	0.242	17.062	67.666	1.897	3.027	0.267	0.016	1.326	97.248
12	4.874	0.394	13.673	71.152	2.710	1.256	0.272	0.040	1.525	95.896

	Na2O	*MgO*	*Al2O3*	*SiO2*	*K2O*	*CaO*	*TiO2*	*MnO*	*FeO*	*Total*
Mean	5.182	0.428	14.184	70.779	2.660	1.503	0.403	0.035	1.808	96.981
Std. Dev.	0.129	0.024	0.220	0.384	0.062	0.066	0.051	0.019	0.065	0.542
Range	0.464	0.086	0.734	1.336	0.203	0.216	0.182	0.063	0.217	1.744
Minimum	4.945	0.381	13.673	70.056	2.579	1.409	0.316	0.000	1.708	95.844
Maximum	5.409	0.467	14.407	71.392	2.782	1.625	0.498	0.063	1.925	97.588
Count	14	14	14	14	14	14	14	14	14	14
CL95.0%	0.075	0.014	0.127	0.222	0.036	0.038	0.030	0.011	0.037	0.313

8a

SAMPLE ID: KEN-CE-1 T376-1 Date of Analysis: 1/98

Raw Probe Data		Raw Probe Data (FeO to Fe2O3)		Recalculated to 100%	
SiO2	70.779			SiO2	72.83
Al2O3	14.184			Al2O3	14.60
FeO	1.808*1.1113=Fe2O3		2.009	Fe2O3	2.07
MgO	0.428			MgO	0.44
MnO	0.035			MnO	0.04
CaO	1.503			CaO	1.55
TiO2	0.403			TiO2	0.41
Na2o	5.182			Na2o	5.33
K2O	2.660			K2O	2.74
TOTAL(O)	96.981	TOTAL(N)	97.182	TOTAL(R)	100.01

20 Best Matches:

1	0.9951		STEM-3, T40-4
2	0.9909	5/26/93	RC92-2 LOCAFE T279-7
3	0.9905	5/29/85	NCT-27 T96-7
4	0.9900		LM-38
5	0.9895		DR-50
6	0.9890		LM-39
7	0.9889	5/26/93	RC-92-1 HICA T279-6
8	0.9867		DR-49
9	0.9866	xx/xx/83	KFF-AF-1-83, T65A-14
10	0.9864	2/28/85	CORN CREEK-1 t89-7
11	0.9858		GS-77
12	0.9857		RC-24
13	0.9857		GS-73
14	0.9855		OMAK-2, T45-8
15	0.9851		GS-75
16	0.9848	1/30/92	FLV-206-LC T249-8
17	0.9846		DR-73
18	0.9844	11/27/91	CHAL-1 T245-2
19	0.9840		LM-22
20	0.9839		DR-53

Elements used in the calculation are:

Na2o
Al2O3
SiO2
K2O
CaO
FeO

***** This sample has been added to the data base *****

H13

H14

Listing of 50 closest matches for COMP. NO. 4095 for elements: Na, Al, Si, K , Ca, Fe Date of Update: 1/29/98

	C.No	Sample Number	Date	SiO2	Al2O3	Fe2O3	MgO	MnO	CaO	TiO2	Na2O	K2O	Total,R	Sim. Co
1	4095	KEN-CE-1 T376-1	1/98	72.83	14.60	2.07	0.44	0.04	1.55	0.41	5.33	2.74	100.01	1.0000
2	364	STEM-3, T40-4		72.75	14.57	2.11	0.44	0.04	1.55	0.44	5.35	2.75	100.00	0.9951
3	3021	RC92-2 LOCAFE T279-7	5/26/93	72.73	14.54	2.04	0.47	0.06	1.55	0.41	5.48	2.72	100.00	0.9909
4	1247	NCT-27 T96-7	5/29/85	72.81	14.62	2.06	0.47	0.06	1.58	0.39	5.24	2.78	100.01	0.9905
5	872	LM-38		72.62	14.74	2.09	0.45	0.06	1.59	0.42	5.32	2.71	100.00	0.9900
6	939	DR-50		72.70	14.64	2.15	0.46	0.05	1.54	0.44	5.31	2.71	100.00	0.9895
7	873	LM-39		72.68	14.66	2.13	0.46	0.04	1.58	0.42	5.32	2.71	100.00	0.9890
8	3018	RC-92-1 HICA T279-6	5/26/93	72.83	14.56	2.03	0.44	0.04	1.52	0.43	5.33	2.81	99.99	0.9889
9	938	DR-49		72.71	14.64	2.12	0.45	0.06	1.56	0.43	5.22	2.81	100.00	0.9867
10	536	KFF-AF-1-83, T65A-14	xx/xx/83	73.02	14.50	2.13	0.44	0.06	1.55	0.42	5.18	2.70	100.00	0.9866
11	1178	CORN CREEK-1 t89-7	2/28/85	72.99	14.54	2.08	0.46	0.06	1.60	0.39	5.16	2.72	100.00	0.9864
12	832	GS-77		72.33	14.95	2.13	0.44	0.06	1.55	0.41	5.32	2.81	100.00	0.9858
13	1001	RC-24		72.52	14.75	2.15	0.42	0.05	1.54	0.44	5.42	2.71	100.00	0.9857
14	828	GS-73		72.88	14.46	2.08	0.45	0.06	1.59	0.45	5.22	2.81	100.00	0.9857
15	246	OMAK-2, T45-8		73.41	14.14	2.09	0.44	0.04	1.56	0.42	5.16	2.74	100.00	0.9855
16	830	GS-75		72.72	14.54	2.17	0.44	0.07	1.59	0.44	5.32	2.71	100.00	0.9851
17	2720	FLV-206-LC T249-8	1/30/92	72.85	14.53	2.11	0.44	0.05	1.62	0.44	5.26	2.71	100.01	0.9848
18	960	DR-73		72.66	14.85	2.06	0.46	0.04	1.58	0.42	5.32	2.61	100.00	0.9846
19	2701	CHAL-1 T245-2	11/27/91	73.18	14.30	2.10	0.44	0.06	1.58	0.41	5.24	2.69	100.00	0.9844
20	866	LM-22		72.62	14.84	2.14	0.46	0.04	1.53	0.44	5.22	2.71	100.00	0.9840
21	942	DR-53		72.75	14.65	2.16	0.46	0.05	1.58	0.43	5.22	2.71	100.01	0.9839
22	1006	RC-33		72.82	14.46	2.15	0.46	0.05	1.61	0.41	5.32	2.71	99.99	0.9838
23	3513	MAZAMA AVR 100 COR		72.79	14.65	2.12	0.46	0.05	1.61	0.42	5.19	2.71	100.00	0.9830
24	3012	CARP-3 T279-2	5/26/93	72.76	14.60	2.04	0.46	0.06	1.49	0.43	5.48	2.68	100.00	0.9828
25	245	OMAK-1, T45-7		73.37	14.32	2.08	0.44	0.02	1.57	0.42	5.07	2.71	100.00	0.9827
26	3957	KL-D86 643-644 T360-6	4/97	73.32	14.37	2.05	0.45	0.04	1.54	0.43	5.02	2.76	99.98	0.9827
27	996	RC-19		72.41	14.76	2.19	0.45	0.05	1.57	0.43	5.42	2.71	99.99	0.9814
28	997	RC-20		72.88	14.66	2.16	0.40	0.06	1.52	0.39	5.32	2.61	100.00	0.9808
29	906	DR-8		72.85	14.75	2.16	0.40	0.04	1.53	0.45	5.12	2.71	100.01	0.9808
30	709	LD-46*		72.74	14.57	2.13	0.45	0.06	1.58	0.43	5.43	2.61	100.00	0.9806
31	1179	DUMP CREEK-1 t89-8	2/28/85	72.99	14.49	2.10	0.47	0.05	1.63	0.43	5.11	2.73	100.00	0.9803
32	999	RC-22		72.40	14.76	2.19	0.44	0.06	1.58	0.43	5.42	2.71	99.99	0.9803
33	2686	RM-RC-1 T243-1	11/13/91	71.99	15.03	2.11	0.43	0.07	1.55	0.44	5.65	2.73	100.00	0.9801
34	817	GS-61		72.90	14.66	2.02	0.43	0.05	1.48	0.42	5.22	2.81	99.99	0.9800
35	898	CB-39		72.67	14.65	2.17	0.48	0.05	1.61	0.44	5.22	2.71	100.00	0.9799
36	816	GS-60		72.94	14.65	2.08	0.45	0.03	1.62	0.41	5.22	2.61	100.01	0.9798
37	1000	RC-23		72.62	14.76	2.16	0.46	0.06	1.58	0.42	5.32	2.61	99.99	0.9794
38	896	CB-37		72.68	14.66	2.15	0.45	0.05	1.63	0.45	5.22	2.71	100.00	0.9793
39	3828	CC10LH144-2 T353-10	1/97	73.16	14.60	2.12	0.46	0.05	1.57	0.38	4.94	2.71	99.99	0.9792
40	998	RC-21		72.40	14.76	2.17	0.45	0.04	1.61	0.44	5.42	2.71	100.00	0.9787
41	3704	VWB 180 T34-5	11/96	73.39	14.44	2.06	0.45	0.06	1.58	0.38	4.95	2.70	100.01	0.9786
42	2687	RM-RC-2 T243-2	11/13/91	73.11	14.36	2.02	0.43	0.07	1.53	0.42	5.46	2.61	100.01	0.9786
43	2782	#4103 T253-3	3/10/92	72.85	14.42	2.20	0.46	0.08	1.49	0.33	5.43	2.74	100.00	0.9785
44	958	DR-71		72.76	14.75	2.11	0.47	0.05	1.60	0.43	5.22	2.61	100.00	0.9784
45	196	LD-38, T3,4		72.72	14.78	2.11	0.46	0.08	1.61	0.43	5.05	2.76	100.00	0.9784
46	876	LM-42		72.60	14.76	2.12	0.45	0.05	1.62	0.46	5.32	2.61	99.99	0.9783
47	710	LD-47*		72.40	14.74	2.18	0.47	0.05	1.61	0.42	5.42	2.71	100.00	0.9782
48	1181	LRR-KP2 t89-10	2/28/85	73.28	14.36	2.13	0.43	0.05	1.57	0.44	5.01	2.72	99.99	0.9782
49	1180	LRR-KP1 74-75 t89-9	2/28/85	72.95	14.67	2.12	0.46	0.05	1.61	0.40	5.03	2.72	100.01	0.9782
50	2435	YOUNG 126-7	08/10/90	72.97	14.68	2.10	0.45	0.05	1.61	0.40	4.98	2.76	100.00	0.9780

10a

Sample KEN-CE-1

Listing of 100 closest matches for COMP. NO. 4095 for elements: **Na, Mg, Al, Si, K , Ca, Ti, Fe** Date of Update: 01/29/98

	C.No	Sample Number	Date	SiO2	Al2O3	Fe2O3	MgO	MnO	CaO	TiO2	Na2O	K2O	Total,R	Sim. Co
1	4095	KEN-CE-1 T376-1	1/98	72.83	14.60	2.07	0.44	0.04	1.55	0.41	5.33	2.74	100.01	1.0000
2	832	GS-77		72.33	14.95	2.13	0.44	0.06	1.55	0.41	5.32	2.81	100.00	0.9893
3	2701	CHAL-1 T245-2	11/27/91	73.18	14.30	2.10	0.44	0.06	1.58	0.41	5.24	2.69	100.00	0.9883
4	364	STEM-3, T40-4		72.75	14.57	2.11	0.44	0.04	1.55	0.44	5.35	2.75	100.00	0.9878
5	536	KFF-AF-1-83, T65A-14	xx/xx/83	73.02	14.50	2.13	0.44	0.06	1.55	0.42	5.18	2.70	100.00	0.9870
6	872	LM-38		72.62	14.74	2.09	0.45	0.06	1.59	0.42	5.32	2.71	100.00	0.9868
7	246	OMAK-2, T45-8		73.41	14.14	2.09	0.44	0.04	1.56	0.42	5.16	2.74	100.00	0.9861
8	3018	RC-92-1 HICA T279-6	5/26/93	72.83	14.56	2.03	0.44	0.04	1.52	0.43	5.33	2.81	99.99	0.9859
9	3021	RC92-2 LOCAFE T279-7	5/26/93	72.73	14.54	2.04	0.47	0.06	1.55	0.41	5.48	2.72	100.00	0.9852
10	245	OMAK-1, T45-7		73.37	14.32	2.08	0.44	0.02	1.57	0.42	5.07	2.71	100.00	0.9840
11	873	LM-39		72.68	14.66	2.13	0.46	0.04	1.58	0.42	5.32	2.71	100.00	0.9833
12	1006	RC-33		72.82	14.46	2.15	0.46	0.05	1.61	0.41	5.32	2.71	99.99	0.9824
13	816	GS-60		72.94	14.65	2.08	0.45	0.03	1.62	0.41	5.22	2.61	100.01	0.9821
14	938	DR-49		72.71	14.64	2.12	0.45	0.06	1.56	0.43	5.22	2.81	100.00	0.9814
15	830	GS-75		72.72	14.54	2.17	0.44	0.07	1.59	0.44	5.32	2.71	100.00	0.9803
16	2720	FLV-206-LC T249-8	1/30/92	72.85	14.53	2.11	0.44	0.05	1.62	0.44	5.26	2.71	100.01	0.9801
17	960	DR-73		72.66	14.85	2.06	0.46	0.04	1.58	0.42	5.32	2.61	100.00	0.9801
18	999	RC-22		72.40	14.76	2.19	0.44	0.06	1.58	0.43	5.42	2.71	99.99	0.9794
19	817	GS-61		72.90	14.66	2.02	0.43	0.05	1.48	0.42	5.22	2.81	99.99	0.9792
20	2359	TWN-L-1.84		73.32	14.45	2.10	0.45	0.00	1.60	0.41	4.93	2.72	99.98	0.9791
21	3827	CC10LH144-1 T353-9	1/97	73.20	14.58	2.14	0.45	0.06	1.56	0.41	4.93	2.67	100.00	0.9790
22	3513	MAZAMA AVR 100 COR		72.79	14.65	2.12	0.46	0.05	1.61	0.42	5.19	2.71	100.00	0.9788
23	1247	NCT-27 T96-7	5/29/85	72.81	14.62	2.06	0.47	0.06	1.58	0.39	5.24	2.78	100.01	0.9788
24	3957	KL-D86 643-644 T360-6	4/97	73.32	14.37	2.05	0.45	0.04	1.54	0.43	5.02	2.76	99.98	0.9784
25	1178	CORN CREEK-1 t89-7	2/28/85	72.99	14.54	2.08	0.46	0.06	1.60	0.39	5.16	2.72	100.00	0.9783
26	939	DR-50		72.70	14.64	2.15	0.46	0.05	1.54	0.44	5.31	2.71	100.00	0.9782
27	2687	RM-RC-2 T243-2	11/13/91	73.11	14.36	2.02	0.43	0.07	1.53	0.42	5.46	2.61	100.01	0.9781
28	961	DR-74		72.85	14.65	2.11	0.46	0.04	1.65	0.41	5.12	2.71	100.00	0.9779
29	2435	YOUNG 126-7	08/10/90	72.97	14.68	2.10	0.45	0.05	1.61	0.40	4.98	2.76	100.00	0.9777
30	996	RC-19		72.41	14.76	2.19	0.45	0.05	1.57	0.43	5.42	2.71	99.99	0.9774
31	2432	YOUNG 124-9	08/10/90	72.78	14.74	2.08	0.45	0.05	1.62	0.42	5.05	2.81	100.00	0.9773
32	804	GS-50		72.74	14.83	2.10	0.45	0.05	1.60	0.42	5.21	2.60	100.00	0.9773
33	709	LD-46*		72.74	14.57	2.13	0.45	0.06	1.58	0.43	5.43	2.61	100.00	0.9769
34	942	DR-53		72.75	14.65	2.16	0.46	0.05	1.58	0.43	5.22	2.71	100.01	0.9767
35	827	GS-72V		72.78	14.66	2.14	0.45	0.06	1.57	0.41	5.02	2.91	100.00	0.9764
36	3705	VWB 180 #2 T341-5	11/96	72.94	14.70	2.10	0.46	0.04	1.58	0.41	4.94	2.83	100.00	0.9762
37	1000	RC-23		72.62	14.76	2.16	0.46	0.06	1.58	0.42	5.32	2.61	99.99	0.9761
38	3012	CARP-3 T279-2	5/26/93	72.76	14.60	2.04	0.46	0.06	1.49	0.43	5.48	2.68	100.00	0.9758

H15

11a

39	743	HC-3		72.89	14.56	2.18	0.44	0.05	1.64	0.41	5.32	2.51	100.00	0.9757
40	828	GS-73		72.88	14.46	2.08	0.45	0.06	1.59	0.45	5.22	2.81	100.00	0.9754
41	1180	LRR-KP1 74-75 t89-9	2/28/85	72.95	14.67	2.12	0.46	0.05	1.61	0.40	5.03	2.72	100.01	0.9752
42	1001	RC-24		72.52	14.75	2.15	0.42	0.05	1.54	0.44	5.42	2.71	100.00	0.9751
43	3699	PLB 130 #2 T341-2	11/96	73.13	14.41	2.08	0.47	0.05	1.62	0.41	5.04	2.80	100.01	0.9744
44	959	DR-72		72.61	14.74	2.15	0.47	0.04	1.65	0.41	5.22	2.71	100.00	0.9743
45	2434	YOUNG 126-6	08/10/90	72.94	14.88	2.07	0.45	0.04	1.60	0.40	4.83	2.78	99.99	0.9742
46	2433	YOUNG 126-1	08/10/90	72.94	14.71	2.08	0.43	0.05	1.64	0.39	5.01	2.76	100.01	0.9741
47	866	LM-22		72.62	14.84	2.14	0.46	0.04	1.53	0.44	5.22	2.71	100.00	0.9740
48	2686	RM-RC-1 T243-1	11/13/91	71.99	15.03	2.11	0.43	0.07	1.55	0.44	5.65	2.73	100.00	0.9737
49	998	RC-21		72.40	14.76	2.17	0.45	0.04	1.61	0.44	5.42	2.71	100.00	0.9727
50	710	LD-47*		72.40	14.74	2.18	0.47	0.05	1.61	0.42	5.42	2.71	100.00	0.9727
51	196	LD-38, T3,4		72.72	14.78	2.11	0.46	0.08	1.61	0.43	5.05	2.76	100.00	0.9725
52	3147	CD10273 T296-1	12/28/93	72.38	14.88	1.96	0.45	0.06	1.66	0.42	5.44	2.77	100.02	0.9723
53	1181	LRR-KP2 t89-10	2/28/85	73.28	14.36	2.13	0.43	0.05	1.57	0.44	5.01	2.72	99.99	0.9723
54	1220	CRL-8 T88-11	5/2/85	72.98	14.29	2.11	0.47	0.05	1.64	0.40	5.25	2.80	99.99	0.9723
55	973	DR-87		72.60	14.74	2.13	0.47	0.06	1.65	0.42	5.21	2.71	99.99	0.9722
56	305	RBW-1286, T5-12		73.26	14.33	2.12	0.43	0.06	1.55	0.43	4.97	2.85	100.00	0.9721
57	3704	VWB 180 T34-5	11/96	73.39	14.44	2.06	0.45	0.06	1.58	0.38	4.95	2.70	100.01	0.9720
58	740	S-23		72.85	14.75	2.14	0.45	0.06	1.59	0.43	5.12	2.61	100.00	0.9720
59	711	LD-48*		72.14	15.05	2.22	0.46	0.07	1.61	0.42	5.32	2.71	100.00	0.9720
60	3694	PLB 15 T340-7	11/96	72.99	14.85	2.08	0.46	0.06	1.54	0.39	5.01	2.62	100.00	0.9717
61	1179	DUMP CREEK-1 t89-8	2/28/85	72.99	14.49	2.10	0.47	0.05	1.63	0.43	5.11	2.73	100.00	0.9715
62	896	CB-37		72.68	14.66	2.15	0.45	0.05	1.63	0.45	5.22	2.71	100.00	0.9706
63	793	GS-37		72.79	14.66	2.12	0.46	0.05	1.67	0.42	5.22	2.61	100.00	0.9706
64	958	DR-71		72.76	14.75	2.11	0.47	0.05	1.60	0.43	5.22	2.61	100.00	0.9700
65	706	LD-38		72.74	14.75	2.11	0.46	0.08	1.61	0.43	5.02	2.81	100.01	0.9699
66	3828	CC10LH144-2 T353-10	1/97	73.16	14.60	2.12	0.46	0.05	1.57	0.38	4.94	2.71	99.99	0.9698
67	3688	GBB 110 T340-3	11/96	73.28	14.45	2.14	0.46	0.04	1.62	0.40	4.86	2.74	99.99	0.9690
68	1106	61384-35 ASW T82-8	10/11/84	72.48	15.22	2.08	0.42	0.10	1.45	0.40	5.24	2.61	100.00	0.9689
69	666	TFM-5, T62-9	08/26/83	73.45	14.40	2.05	0.41	0.05	1.50	0.43	5.02	2.70	100.01	0.9686
70	733	S-11		73.17	14.65	2.10	0.45	0.06	1.62	0.42	5.02	2.51	100.00	0.9683
71	831	GS-76		72.95	14.65	2.11	0.46	0.06	1.60	0.44	5.12	2.61	100.00	0.9683
72	977	DR-93		72.83	14.45	2.17	0.48	0.05	1.69	0.41	5.22	2.71	100.01	0.9682
73	997	RC-20		72.88	14.66	2.16	0.40	0.06	1.52	0.39	5.32	2.61	100.00	0.9681
74	737	S-16		72.91	14.84	2.12	0.45	0.06	1.55	0.44	5.11	2.51	99.99	0.9679
75	3921	T2-1/10-D (2) minor T357-10	3/97	73.33	14.63	2.06	0.48	0.06	1.57	0.42	4.75	2.70	100.00	0.9679
76	1217	CRL-3 T88-8	5/2/85	72.76	14.38	2.16	0.48	0.05	1.64	0.40	5.30	2.83	100.00	0.9678
77	798	GS-43		72.67	14.75	2.15	0.45	0.05	1.67	0.43	5.22	2.61	100.00	0.9677
78	876	LM-42		72.60	14.76	2.12	0.45	0.05	1.62	0.46	5.32	2.61	99.99	0.9674
79	2899	FLV-1.5 T267-4	10/27/92	72.10	14.96	2.09	0.47	0.05	1.65	0.39	5.55	2.72	99.98	0.9670
80	897	CB-38		72.61	14.74	2.19	0.46	0.05	1.58	0.44	5.11	2.81	99.99	0.9670
81	966	DR-80		72.62	14.66	2.14	0.48	0.07	1.66	0.43	5.22	2.71	99.99	0.9666
82	1435	WASCO-97 T114-4	12/12/85	73.25	14.51	2.10	0.45	0.06	1.60	0.45	4.84	2.72	99.98	0.9665

83	2436	YOUNG C128-2	08/10/90	73.34	14.37	2.13	0.43	0.06	1.51	0.42	4.85	2.90	100.01	0.9664
84	690	RS-M		73.28	14.32	1.96	0.46	0.00	1.65	0.42	5.11	2.80	100.00	0.9664
85	1808	DS-LCC-2 T144-2	7/21/87	73.68	13.82	2.14	0.47	0.06	1.59	0.42	5.05	2.76	99.99	0.9662
86	1810	DS-LCC-L1 (2) T144-3	7/21/87	73.62	14.10	2.08	0.44	0.02	1.60	0.36	5.10	2.67	99.99	0.9660
87	898	CB-39		72.67	14.65	2.17	0.48	0.05	1.61	0.44	5.22	2.71	100.00	0.9660
88	795	GS-39		72.85	14.65	2.17	0.45	0.04	1.68	0.43	5.12	2.61	100.00	0.9647
89	2345	FLV-71-FC T195-5	7/21/89	73.10	14.41	2.11	0.48	0.07	1.68	0.42	5.05	2.69	100.01	0.9636
90	803	GS-49		72.58	14.86	2.10	0.45	0.05	1.68	0.45	5.22	2.61	100.00	0.9635
91	799	GS-44		72.54	14.85	2.15	0.46	0.04	1.72	0.42	5.22	2.61	100.01	0.9635
92	906	DR-8		72.85	14.75	2.16	0.40	0.04	1.53	0.45	5.12	2.71	100.01	0.9631
93	1216	CRL-2 T88-7	5/2/85	72.88	14.35	2.15	0.48	0.05	1.65	0.38	5.28	2.78	100.00	0.9630
94	3891	T2-1/10-D MIN2 T357-10	2/97	73.06	14.82	2.20	0.47	0.05	1.53	0.40	4.79	2.69	100.01	0.9628
95	800	GS-45		72.83	14.65	2.20	0.45	0.04	1.69	0.43	5.12	2.61	100.02	0.9624
96	1107	61384-36 ASW T82-9	10/11/84	72.63	15.15	2.08	0.42	0.09	1.45	0.38	5.18	2.61	99.99	0.9622
97	995	RC-18		72.35	14.75	2.22	0.46	0.07	1.59	0.44	5.52	2.61	100.01	0.9621
98	1219	CRL-5 T88-10	5/2/85	73.10	14.38	2.15	0.48	0.06	1.60	0.39	5.03	2.82	100.01	0.9620
99	797	GS-42		72.90	14.94	2.04	0.39	0.05	1.43	0.42	5.11	2.71	99.99	0.9618
100	843	GS-89		72.53	14.85	2.20	0.41	0.03	1.51	0.44	5.42	2.61	100.00	0.9617

13a

Appendix I

Reports of Radiocarbon Dating Analyses

BETA ANALYTIC INC.

RADIOCARBON DATING SERVICES

Dr. MURRY A. TAMERS
Mr. DARDEN G. HOOD
Directors

RONALD E. HATFIELD
Laboratory Manager

CHRISTOPHER PATRICK
TERESA A. ZILKO-MILLER
Associate Managers

January 29, 1998

Mr. Joseph B. Dunbar
US Army Corps of Engineers
Waterways Experiment Station
CEWES-66Y
3909 Halls Ferry Road
Vicksburg, MS 39180

Dear Joe:

Please find enclosed the radiocarbon dating results for two fresh water shell (samples CPPOO5-60-80 and CPP200-60-65). One was large enough for radiometric counting and was analyzed on the PRIORITY basis. The other one was was very small and was analyzed using AMS (on the ADVANCE basis). The method for each is listed on the report sheet. All analytical steps went normally. As always, literature discussing the generalities of analysis and calendar calibration are enclosed. If you have any specific questions, please do not hesitate to contact us.

Our invoice is enclosed. Please, immediately give it to the appropriate office for prompt payment or send VISA charge authorization. Thank you.

Sincerely,

Darden Hood

4985 S.W. 74 COURT MIAMI FL 33155 U.S.A
TELEPHONE: 305-667-5167 / FAX: 305-663-0964 / INTERNET: beta@radiocarbon.com
WEB SITE: http://www.radiocarbon.com

β

BETA ANALYTIC INC.

DR. M.A. TAMERS and MR. D.G. HOOD

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REPORT OF RADIOCARBON DATING ANALYSES

FOR: Mr. Joseph B. Dunbar
US Army Corps of Engineers

DATE RECEIVED: Jan. 20 & 22, 1998
DATE REPORTED: January 29, 1998

Sample Data	Measured C14 Age	C13/C12 Ratio	Conventional C14 Age (*)
Beta-113838	6230 +/- 60 BP	- 8.2 o/oo	6510 +/- 60 BP

SAMPLE #: CPP005-60-80
ANALYSIS: ADVANCE-AMS
MATERIAL/PRETREATMENT:(shell): acid etch

Beta-113977	5820 +/- 80 BP	- 8.3 o/oo	6090 +/- 80 BP

SAMPLE #: CPP200-60-65
ANALYSIS: radiometric-PRIORITY
MATERIAL/PRETREATMENT:(shell): acid etch

NOTE: It is important to read the calendar calibration information and to use the calendar calibrated results (reported separately) when interpreting these results in AD/BC terms.

Dates are reported as RCYBP (radiocarbon years before present, "present" = 1950A.D.). By International convention, the modern reference standard was 95% of the C14 content of the National Bureau of Standards' Oxalic Acid & calculated using the Libby C14 half life (5568 years). Quoted errors represent 1 standard deviation statistics (68% probability) & are based on combined measurements of the sample, background, and modern reference standards.

I2

Measured C13/C12 ratios were calculated relative to the PDB-1 international standard and the RCYBP ages were normalized to -25 per mil. If the ratio and age are accompanied by an (*), then the C13/C12 value was estimated, based on values typical of the material type. The quoted results are NOT calibrated to calendar years. Calibration to calendar years should be calculated using the Conventional C14 age.

BETA ANALYTIC INC.
RADIOCARBON DATING SERVICES

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Mr. DARDEN G. HOOD
Directors

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ANALYTICAL PROCEDURES AND FINAL REPORT

FINAL REPORT

This package includes the final date report, this statement outlining our analytical procedures, a glossary of pretreatment terms, calendar calibration information, billing documents (containing balance/credit information and the number of samples submitted within the yearly discount period), and peripheral items to use with future submittals. The final report includes the individual analysis method, the delivery basis, the material type and the individual pretreatments applied. Please recall any correspondences or communications we may have had regarding sample integrity, size, special considerations or conversions from one analytical technique to another (e.g. radiometric to AMS). The final report has also been sent by fax or e-mail, where available.

PRETREATMENT

Results were obtained on the portion of suitable carbon remaining after any necessary chemical and mechanical pretreatments of the submitted material. Pretreatments were applied, where necessary, to isolate ^{14}C which may best represent the time event of interest. Individual pretreatments are listed on the report next to each result and are defined in the enclosed glossary. When interpreting the results, it is important to consider the pretreatments. Some samples cannot be fully pretreated making their ^{14}C ages more subjective than samples which can be fully pretreated. Some materials receive no pretreatments. Please read the pretreatment glossary.

ANALYSIS

Materials measured by the radiometric technique were analyzed by synthesizing sample carbon to benzene (92% C), measuring for ^{14}C content in a scintillation spectrometer, and then calculating for radiocarbon age. If the Extended Counting Service was used, the ^{14}C content was measured for a greatly extended period of time. AMS results were derived from reduction of sample carbon to graphite (100 %C), along with standards and backgrounds. The graphite was then sent for ^{14}C measurement in an accelerator-mass-spectrometer located at one of six collaborating facilities; Lawrence Livermore National Laboratory (LLNL) in California, Eidgenössische Technische Hochschule University (ETH) in Zürich, Oxford University in England, The New Zealand Institute of Nuclear and Geological Sciences (GNS), Groningen University in The Netherlands, or The University of Kiel in Germany.

THE RADIOCARBON AGE AND CALENDAR CALIBRATION

The "Conventional C14 Age (*)" is the result after applying C13/C12 corrections to the measured age and is the most appropriate radiocarbon age (the "*" is discussed at the bottom of the final report). Applicable calendar calibrations are included for organic materials and fresh water carbonates between 0 and 10,000 BP and for marine carbonates between 0 and 8,300 BP. If certain calibrations are not included with this report, the results were either too young, too old, or inappropriate for calibration.

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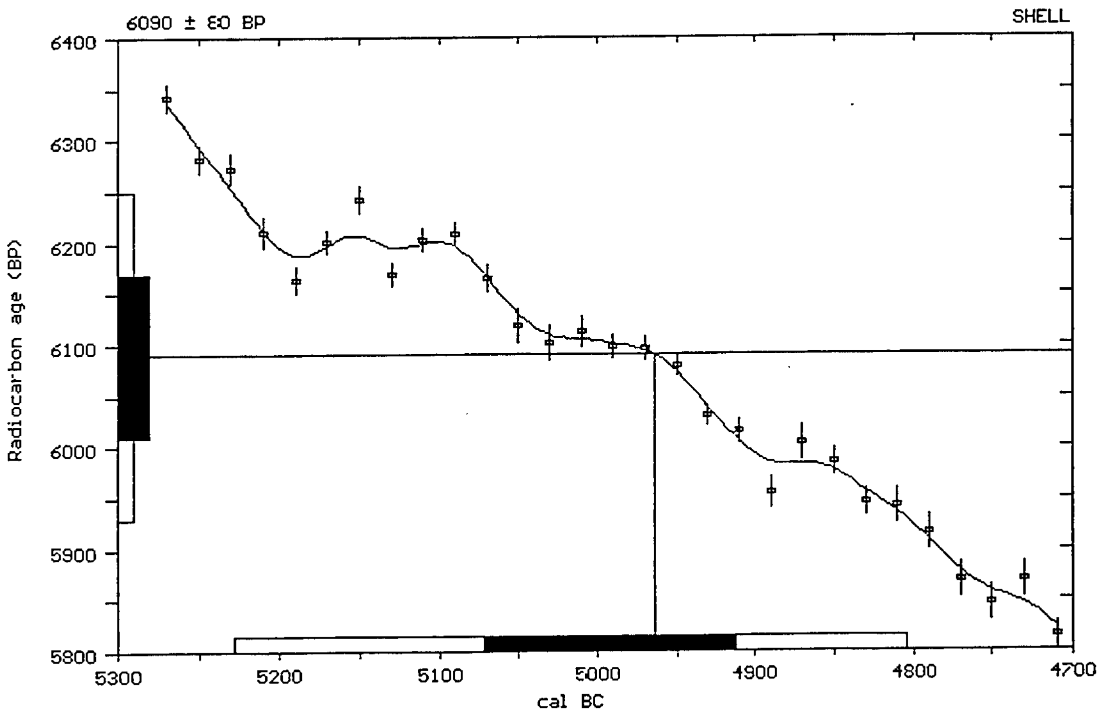
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables:C13/C12=-8.3:lab mult.=1)

Laboratory Number:	Beta-113977
Conventional radiocarbon age:	**6090 ± 80 BP**
Calibrated results: **(2 sigma, 95% probability)**	**cal BC 5230 to 4805**

Intercept data:

Intercept of radiocarbon age with calibration curve:	cal BC 4965
1 sigma calibrated results: (68% probability)	cal BC 5070 to 4915



References:

Pretoria Calibration Curve for Short Lived Samples
Vogel, J. C., Fuls, A., Visser, E. and Becker, B., 1993, Radiocarbon 35(1), p73-86

A Simplified Approach to Calibrating C14 Dates
Talma, A. S. and Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

Calibration - 1993
Stuiver, M., Long, A., Kra, R. S. and Devine, J. M., 1993, Radiocarbon 35(1)

Beta Analytic Radiocarbon Dating Laboratory

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables:C13/C12=-8.2:lab mult.=1)

Laboratory Number: Beta-113838

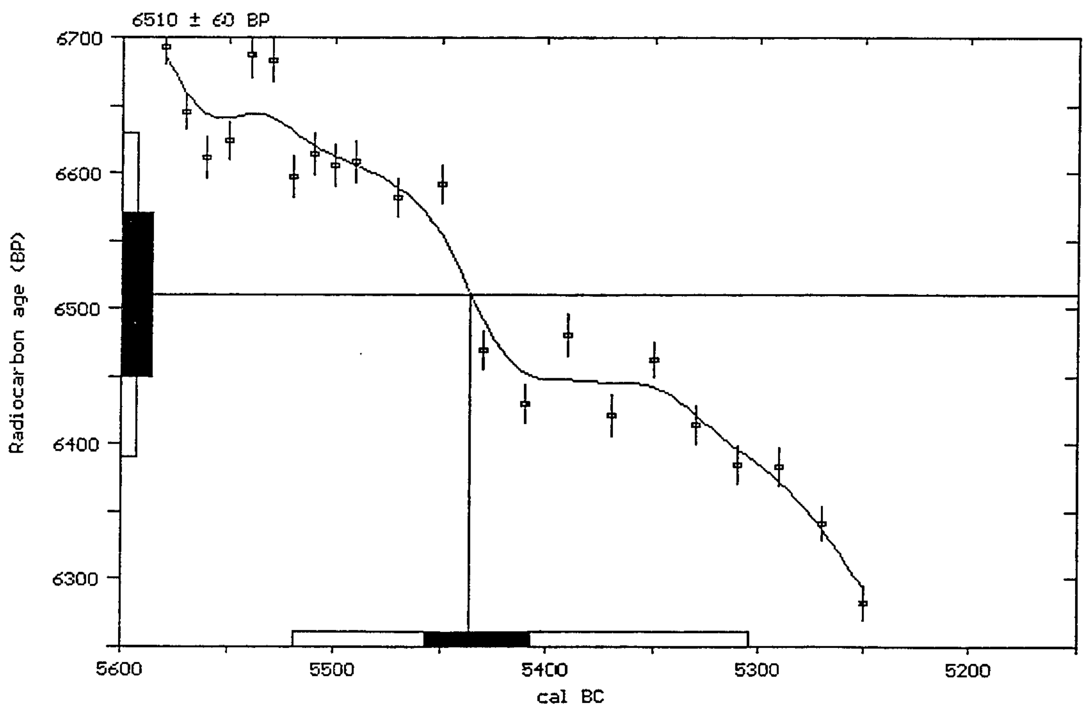
Conventional radiocarbon age: 6510 ± 60 BP

Calibrated results: cal BC 5520 to 5305
(2 sigma, 95% probability)

Intercept data:

Intercept of radiocarbon age with calibration curve: cal BC 5435

1 sigma calibrated results: cal BC 5455 to 5405
(68% probability)



References:

Pretoria Calibration Curve for Short Lived Samples
Vogel, J. C., Fuls, A., Visser, E. and Becker, B., 1993, Radiocarbon 35(1), p73-86
A Simplified Approach to Calibrating C14 Dates
Talma, A. S. and Vogel, J. C., 1993, Radiocarbon 35(2), p317-322
Calibration - 1993
Stuiver, M., Long, A., Kra, R. S. and Devine, J. M., 1993, Radiocarbon 35(1)

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BETA ANALYTIC INC.
RADIOCARBON DATING LABORATORY
CALIBRATED C-14 DATING RESULTS

Calibrations of radiocarbon age determinations are applied to convert BP results to calendar years. The short term difference between the two is caused by fluctuations in the heliomagnetic modulation of the galactic cosmic radiation and, recently, large scale burning of fossil fuels and nuclear devices testing. Geomagnetic variations are the probable cause of longer term differences.

The parameters used for the corrections have been obtained through precise analyses of hundreds of samples taken from known-age tree rings of oak, sequoia, and fir up to 7,200 BP. The parameters for older samples, up to 22,000 BP, as well as for all marine samples, have been inferred from other evidence. Calibrations are presently provided for terrestrial samples to about 10,000 BP and marine samples to about 8,300 BP.

The Pretoria Calibration Procedure program has been chosen for these dendrocalibrations. It uses splines through the tree-ring data as calibration curves, which eliminates a large part of the statistical scatter of the actual data points. The spline calibration allows adjustment of the average curve by a quantified closeness-of-fit parameter to the measured data points. On the following calibration curves, the solid bars represent one sigma statistics (68% probability) and the hollow bars represent two sigma statistics (95% probability). Marine carbonate samples that have been corrected for δ 13/12C, have also been corrected for both global and local geographic reservoir effects (as published in Radiocarbon, Volume 35, Number 1, 1993) prior to the calibration. Marine carbonates that have not been corrected for δ 13/12C, have been adjusted by an assumed value of 0 ‰ in addition to the reservoir corrections. Reservoir corrections for fresh water carbonates are usually unknown and are generally not accounted for in those calibrations. In the absence of measured δ 13/12C ratios, a typical value of -5 ‰ was assumed for freshwater carbonates. There are separate calibration data for the Northern and Southern Hemisphere. Variables used in each calibration are listed below the title of each calibration page.

(Caveat: the calibrations assume that the material dated was living for exactly ten or twenty years (e.g. a collection of 10 or 20 individual tree rings taken from the outer portion of a tree that was cut down to produce the sample in the feature dated). For other materials, the maximum and minimum calibrated age ranges given by the computer program are uncertain. The possibility of an "old wood effect" must also be considered, as well as the potential inclusion of some younger material in the total sample. Since the vast majority of samples dated probably will not fulfill the ten/twenty-year-criterium and, in addition, an old wood effect or young carbon inclusion might not be excludable, these dendrocalibration results should be used only for illustrative purposes. In the case of carbonates, reservoir correction is theoretical and the local variations are real, highly variable and dependant on provenience. The age ranges and, especially, the intercept ages generated by the program must be considered as approximations.)

EXPLANATION OF THE BETA ANALYTIC DENDRO-CALIBRATION PRINTOUT

CALIBRATION OF RADICARBON AGE TO CALENDAR YEARS

Variables used in the calculation of age calibration → **(Variables: C13/C12= :Delta-R= :Glob res= :lab. multi=1)**

Laboratory Number: Beta-12345

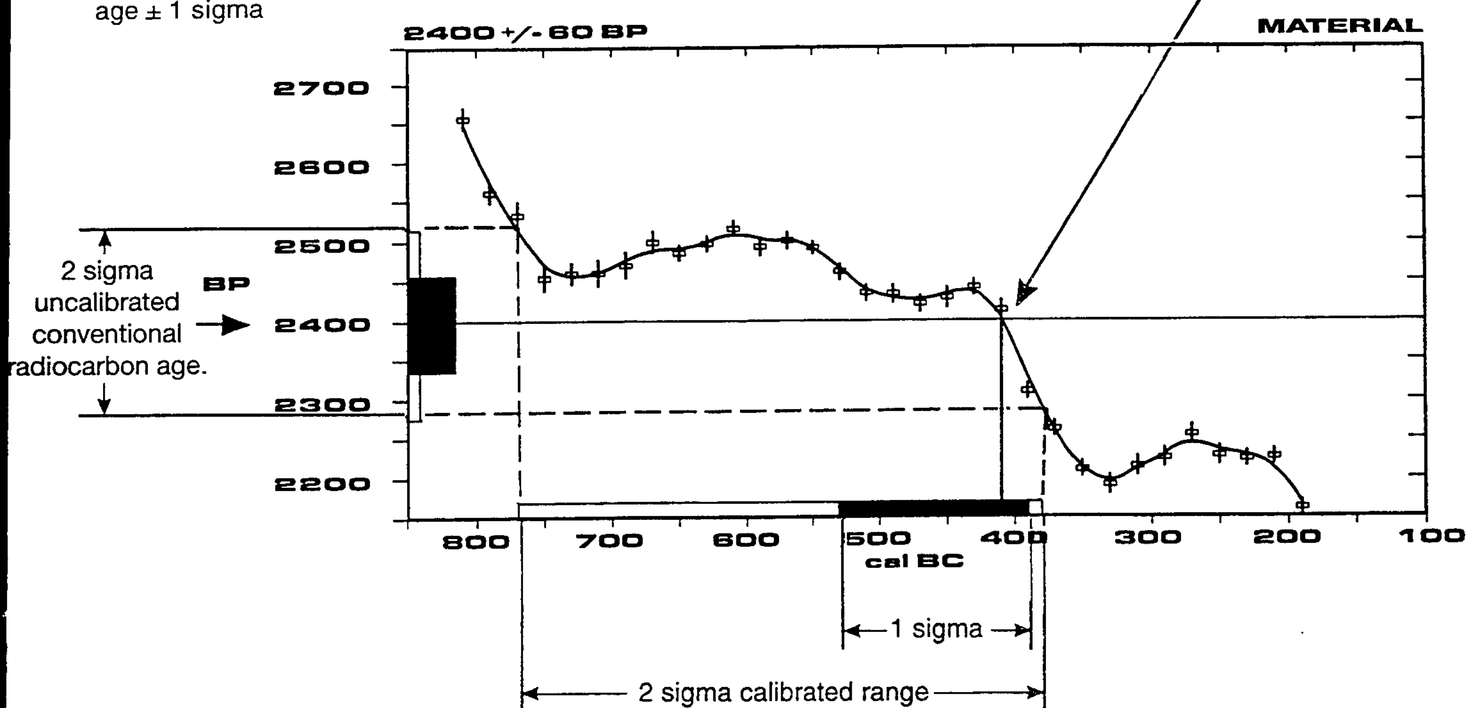
Conventional radiocarbon age: **2400 +/- 60 BP** — The uncalibrated conventional radiocarbon age (± 1 sigma)

The recommended calibration age range to be used for interpretation → **Calibrated result: (2 sigma, 95% probability)** **cal BC 770 to 380**

Intercept data:

Intercept of conventional radiocarbon age with calibration curve: cal BC 410 ← The intercept between the conventional radiocarbon age and the calibrated calendar time scale curve.

The calibration result of the conventional radiocarbon age ± 1 sigma → 1 sigma calibrated result: (68% probability) cal BC 530 to 390



References:

Pretoria Calibration Curve for Short Lived Samples
Vogel, J.C., Fuls, A., Visser, E. and Becker, B., 1993, Radiocarbon 35(I), p73-86

A Simplified Approach to Calibrating C14 Dates
Talma, A.S. and Vogel, J.C., 1993, Radiocarbon 35(2), p317-322

Calibration - 1993
Stuiver, M., Long, A., Kra, R.S. and Devine, J.M., 1993, Radiocarbon 35(I)

Reporting results (recommended):
1. List the conventional radiocarbon age with its associated 1 sigma standard deviation in a table and designate it as such.
2. Discussion of ages in the text should focus on the 2 sigma calibrated range.

PRETREATMENT GLOSSARY

Pretreatment of submitted materials is required to eliminate secondary carbon components. These components, if not eliminated, could result in a radiocarbon date which is too young or too old. Pretreatment does not ensure that the radiocarbon date will represent the time event of interest. This is determined by the sample integrity. The old wood effect, burned intrusive roots, bioturbation, secondary deposition, secondary biogenic activity incorporating recent carbon (bacteria) and the analysis of multiple components of differing age are just some examples of potential problems. The pretreatment philosophy is to reduce the sample to a single component, where possible, to minimize the added subjectivity associated with these types of problems.

"acid/alkali/acid"

The sample was first gently crushed/dispersed in deionized water. It was then given hot HCl acid washes to eliminate carbonates and alkali washes (NaOH) to remove secondary organic acids. The alkali washes were followed by a final acid rinse to neutralize the solution prior to drying. Chemical concentrations, temperatures, exposure times, and number of repetitions, were applied accordingly with the uniqueness of the sample. Each chemical solution was neutralized prior to application of the next. During these serial rinses, mechanical contaminants such as associated sediments and rootlets were eliminated. This type of pretreatment is considered a "full pretreatment". On occasion the report will list the pretreatment as "acid/alkali/acid - insolubles" to specify which fraction of the sample was analyzed. This is done on occasion with sediments (See "acid/alkali/acid - solubles"

Typically applied to: charcoal, wood, some peats, some sediments, textiles

"acid/alkali/acid - solubles"

On occasion the alkali soluble fraction will be analyzed. This is a special case where soil conditions imply that the soluble fraction will provide a more accurate date. It is also used on some occasions to verify the present/absence or degree of contamination present from secondary organic acids. The sample was first pretreated with acid to remove any carbonates and to weaken organic bonds. After the alkali washes (as discussed above) are used, the solution containing the alkali soluble fraction is isolated/filtered and combined with acid. The soluble fraction which precipitates is rinsed and dried prior to combustion.

"acid washes"

Surface area was increased as much a possible. Solid chunks were crushed, fibrous materials were shredded, and sediments were dispersed. Acid (HCl) was applied repeatedly to ensure the absence of carbonates. Chemical concentrations, temperatures, exposure times, and number of repetitions, were applied accordingly with the uniqueness of each sample. The sample, for a number of reasons, could not be subjected to alkali washes to ensure the absence of secondary organic acids. The most common reason is that the primary carbon is soluble in the alkali. Dating results reflect the total organic content of the analyzed material. Their accuracy depends on the researcher's ability to subjectively eliminate potential contaminants based on contextual facts.

Typically applied to: organic sediments, some peats, small wood or charcoal, special cases

"collagen extraction"

The material was first tested for friability ("softness"). Very soft bone material is an indication of the potential absence of the collagen fraction (basal bone protein acting as a "reinforcing agent" within the crystalline apatite structure). It was then washed in de-ionized water and gently crushed. Dilute, cold HCl acid was repeatedly applied and replenished until the mineral fraction (bone apatite) was eliminated. The collagen was then dissected and inspected for rootlets. Any rootlets present were also removed when replenishing the acid solutions. Where possible, usually dependant on the amount of collagen available, alkali (NaOH) was also applied to ensure the absence of secondary organic acids.

I8

Typically applied to: bones

"acid etch"

The calcareous material was first washed in de-ionized water, removing associated organic sediments and debris (where present). The material was then crushed/dispersed and repeatedly subjected to HCl etches to eliminate secondary carbonate components. In the case of thick shells, the surfaces were physically abraded prior to etching down to a hard, primary core remained. In the case of porous carbonate nodules and caliche, very long exposure times were applied to allow infiltration of the acid. Acid exposure times, concentrations, and number of repetitions, were applied accordingly with the uniqueness of the sample.

Typically applied to: shells, caliche, calcareous nodules

"neutralized"

Carbonates precipitated from ground water are usually submitted in an alkaline condition (ammonium hydroxide or sodium hydroxide solution). Typically this solution is neutralized in the original sample container, using deionized water. If larger volume dilution was required, the precipitate and solution were transferred to a sealed separatory flask and rinsed to neutrality. Exposure to atmosphere was minimal.

Typically applied to: Strontium carbonate, Barium carbonate
(i.e. precipitated ground water samples)

"none"

No laboratory pretreatments were applied. Special requests and pre-laboratory pretreatment usually accounts for this.

"acid/alkali/acid/cellulose extraction"

Following full acid/alkali/acid pretreatments, the sample is rinsed in NaClO2 under very controlled conditions (Ph = 3, temperature = 70 degrees C). This eliminates all components except wood cellulose. It is useful for woods which are either very old or highly contaminated.

Applied to: wood

"carbonate precipitation"

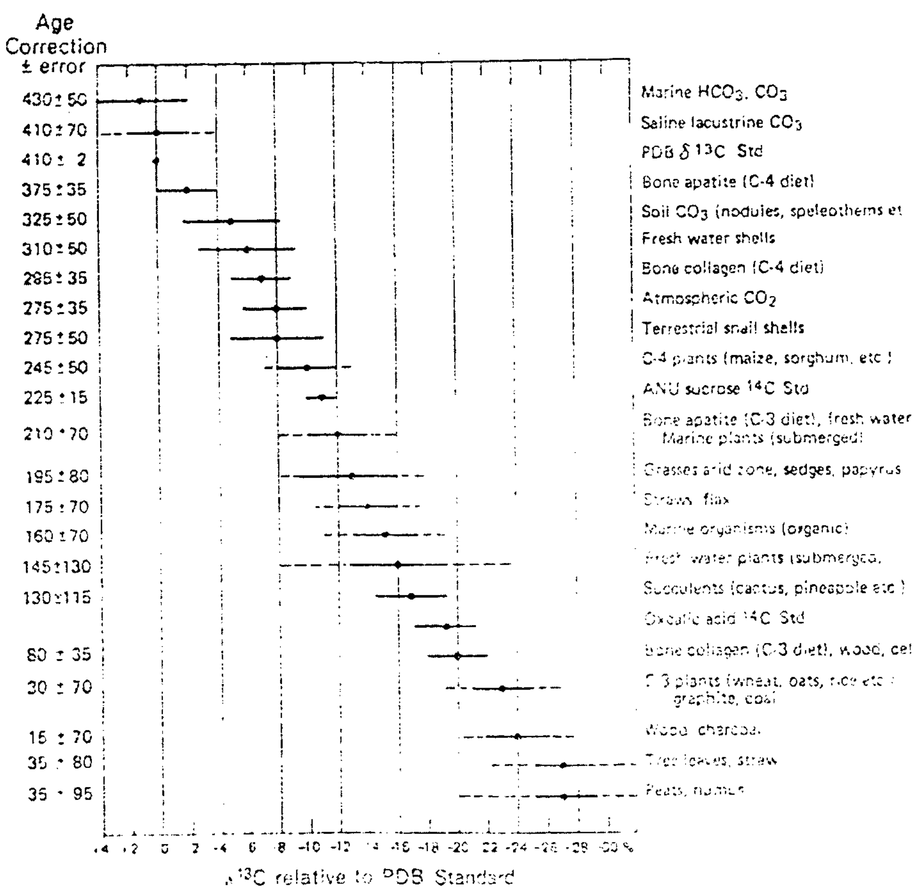
Dissolved carbon dioxide and carbonate species are precipitated from submitted water by complexing them as amonium carbonate. Strontium chloride is added to the ammonium carbonate solution and strontium carbonate is precipitated for the analysis. The result is representative of the dissolved inorganic carbon within the water. Results are reported as "water DIC".

Applied to: water

Derivation of a radiometric or accelerator dendro-calibrated (CALENDAR) date requires use of a CONVENTIONAL radiocarbon date (Stuiver and Polach)[1]. The conventional date is a basic radiocarbon date that has been normalized to the modern standard through the use of C13/C12 ratios* (analyzed or estimated). The statistical error (+/-) on an analyzed C13/C12 value is quite small and does not contribute significantly to the combined error on the date. However, use of an estimated C13/C12 ratio for an unknown sample may incur a very large combined error term. This is clearly illustrated in the figure below (Gupta & Polach; modified by J. Head)[2] where the possible range of C13/C12 values for a particular material type may be so large as to preclude any practical application or correction.

In cases where analyzed C13/C12 values are not available, we have provided (for illustration) dendro-calibrations assuming a mean "chart" value, but without an estimated error term.

Where a sample carbon reservoir different from the modern oxalic acid/wood modern standard (e.g. shell) is involved, a further correction must be employed; the necessary variables are displayed on the calibration sheet.



[1]Stuiver, M. and Polach, H.A., 1977. Discussion: Reporting of 14-C data, Radiocarbon, 19, 355-363.

[2]Gupta S.K. and Polach H.A., 1985. Radiocarbon dating practices at ANU Handbook, p.114. Radiocarbon Laboratory, Research School of Pacific Studies, ANU, Canberra.

*Radiocarbon is incorporated into various materials by different pathways and this introduces differing degrees of isotopic fractionation. The C13/C12 ratio of any material is the millesimal difference of the sample to the carbonate PDB standard and is directly related to the C14/C12 ratio. The degree of sample C-14 enrichment or depletion then is normalized to that of the modern standard.

U.S. GEOLOGICAL SURVEY

CLIMATE HISTORY/HAZARDS PROGRAM

^{14}C LABORATORY

^{14}C Results for: Joseph Dunbar

WW	SAMPLE ID	MATERIAL	REGION	δ ^{13}C	^{14}C AGE	+/-	DATED ON
1626	CPC 059.5 10-20cm	core sed.	Kennewick	-25	9010	50	3/15/98
1627	CPC 059.5 190-200cm	core sed.	Kennewick	-25	15330	60	3/15/98

U.S. GEOLOGICAL SURVEY
CLIMATE HISTORY/HAZARD PROGRAM
^{14}C LABORATORY

NOTES:

- Samples were processed at the ^{14}C Laboratory of the U.S. Geological Survey in Reston, Virginia.
- ^{14}C ages were determined at the Center for Accelerator Mass Spectrometry (CAMS), Lawrence Livermore National Laboratory, Livermore, California.
- The quoted age is in radiocarbon years (BP) using the Libby half life of 5568 years.
- WW is the identification assigned to a sample by the USGS ^{14}C Laboratory.
- Values reported for $\delta^{13}C$ are the assumed values according to Stuiver and Polach (Radiocarbon, v. 19, p.355, 1977) when given without decimal places. Values measured for the material itself are given with a single decimal place.

Comments or questions may be referred to:

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U.S. GEOLOGICAL SURVEY

CLIMATE HISTORY/HAZARDS PROGRAM

^{14}C LABORATORY

^{14}C Results for: Joe Dunbar

WW	SAMPLE ID	MATERIAL	REGION	$\delta^{13}C$	^{14}C AGE	+/-	DATED ON
1737	CPC 059.5 130-138cm	organic sed	Kennewick	-25	12460	50	5/6/98
1738	CPC 059.5 220-229cm	organic sed	Kennewick	-25	14580	50	5/6/98

I13

U.S. GEOLOGICAL SURVEY
CLIMATE HISTORY/HAZARD PROGRAM
^{14}C LABORATORY

NOTES:

- Samples were processed at the ^{14}C Laboratory of the U.S. Geological Survey in Reston, Virginia.
- ^{14}C ages were determined at the Center for Accelerator Mass Spectrometry (CAMS), Lawrence Livermore National Laboratory, Livermore, California.
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REPORT DOCUMENTATION PAGE

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5. FUNDING NUMBERS

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Lillian D. Wakeley, William L. Murphy, Joseph B. Dunbar, Andrew G. Warne, Frederick L. Briuer, Paul R. Nickens

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Consulting Archaeologist, 5168 North Windriver Place, Tucson, AZ 85750

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13. ABSTRACT *(Maximum 200 words)*

The site of the discovery of the ancient human remains known as Kennewick Man has gained international attention. On-site study during December 1997 focused principally on one question: Is the geologic setting consistent with the 9,000-yr age reported for the human remains? Other objectives for the study included determining if there was evidence for a specific cultural affiliation for the remains, if there was evidence for either intentional of accidental burial, and if the stratigraphic layers were in place. The principal landform at the site is a terrace of the Columbia River, comprising fine-grained sediments accumulated in quiet water. The presence of the Mazama tephra, a volcanic ash later correlated throughout the Pacific Northwest, established that this landform is more than 6,700 years old. Stratigraphic horizons traceable over the length of the study site provided datable materials to indicate that the layers are relatively undisturbed and span at least 15,000 years of geologic time. No evidence for cultural affiliation was encountered, and the question of accidental versus intentional burial is still open. The limited scope of this study did not allow definition of the three-dimensional geometry of the landform and its relationship to regional geology.

14. SUBJECT TERMS	15. NUMBER OF PAGES
See reverse.	240
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

14. (Concluded).

Alluvial deposition	Kennewick Man	River Terrace
Bank erosion	Lake Wallula	Shell middens
Columbia River	Mazama tephra	Soils
Flood deposits	Pasco Basin	Stratigraphy
Geoarchaeology	Pedogenesis	Tephrochronology
Geomorphology	Pleistocene	Touchet beds
Holocene	Radiometric dating	Vibracore